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EDITORIAL.

ITEMS AND NOVELTIES.

The Pulsometer.—The plate herewith shown, represents respectively perspective and sectional views of a novel machine for elevating water, designated by the above name, and which has of late attracted much attention on the part of the technical press of the country. To indicate the novelty of its construction, it is sufficient to say that it is a steam pump, operating without cylinder, piston, piston-rod, stuffing-boxes, glands, cams, excentrics, slide-valves, cranks or fly-wheels; but, on the contrary, is a construction in which steam and water are brought directly in contact, in certain chambers where the alternating vacuum and pressure exerted by the steam is simply utilized to lift and force the water by a species of pulsating action.

The internal construction of this curious apparatus may be understood upon inspection of the sectional view (figure 2), from which it will be seen that it is composed principally of two chambers, A A, of bottle shape, joined together side by side, with long tapering necks, bent towards each other and uniting at S, forming a common upright passage, into which a small metal ball is fitted, so as to oscillate with a slight rolling motion between the seats formed in the junction, thereby preventing the entrance of steam into whichever

passage it may fall. These chambers are also connected, at their lower ends, with the vertical induction passage, D, through circular orifices, in which spherical shells are seated and arranged to roll up and down with a limited range of motion, and thereby act as induction valves to the chambers A A respectively. A delivery passage, common to both chambers, is also provided at *h*, as shown in dotted section in fig. 2, and in full in fig. 1. This delivery passage also contains a spherical shell or ball, which oscillates from side to side, between seatings formed in the entrance to the passages leading into chambers A A, and acts as a delivery valve to each alternately. B represents a vacuum chamber, formed between the necks of chambers A A, and is connected with the induction passage through a downward extension (not shown) on the side opposite from passage *h*. *b b* represent flanges covering openings in the bottom of chambers A A, arranged to facilitate the removal of the shell valves when necessary. These flanges have studs or guards cast on their inner faces, to confine the shells to their proper range of motion. The entire apparatus, with all its chambers and passages, is cast in one piece, and at the same time with the induction shell valves in their proper positions, thereby forming their respective seats; while chills of suitable form are placed so as to mould the seats of the steam and discharge valves also. Stud bolts are also cast in their proper positions on all the flanged passages, ready for the screwing on of the flanges.

Steam being at the requisite pressure, and the suction pipe and chambers filled with water, the pulsometer is ready to operate. Now, if steam be admitted into the passage above the little ball near the top of the pump, it will pass into whichever chamber the position of the ball permits, and as the steam enters the chamber directly above the water, and in a manner to secure the least amount of condensation, presses upon the water therein, and forces it out past the discharge ball-valve, and out through the discharge-pipe, to any point desired, with a force equal to the pressure of the steam in the boiler operating it.

Now, when the steam has expelled the water as above described, and the water line has finally become depressed until the upper edge of the water outlet therefrom becomes exposed to the steam pressure, the steam which has filled the chamber suddenly escapes through this water outlet and, mingling with and suddenly agitating the water, instantly condenses, and, owing to the peculiar form of the outlet and its relation to the contiguous chamber, the steam not only escapes

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Items, Plate VII.

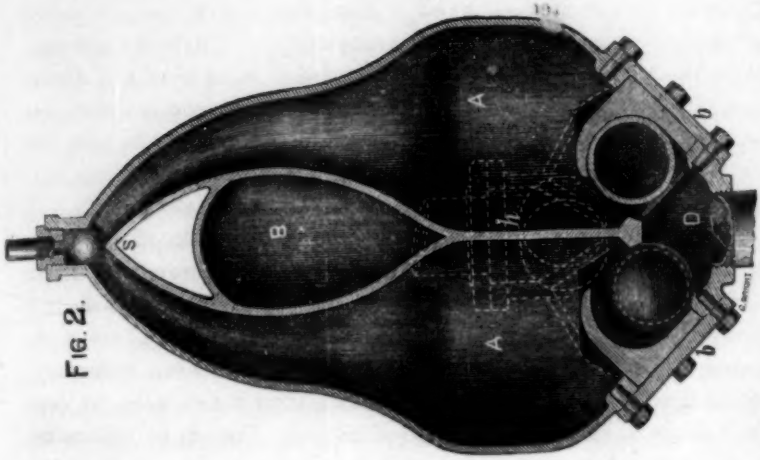

FIG. 2.

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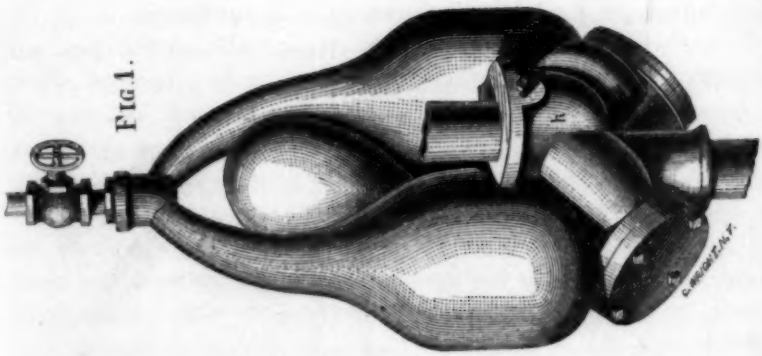


FIG. 1.

THE PULSOMETER.

chamber, and allows a little air to enter, but closes against its return. It will open at each pulsation, and its lift; consequently the quantity of air entering the chamber may be regulated by a little milled nut, the operation of which will be readily understood.

instantly condenses, and, owing to the peculiar form of the outlet and its relation to the contiguous chamber, the steam not only escapes

instantly and condenses, but a nearly perfect vacuum is also produced therein. The ball at the junction of the necks of the chambers (as shown in fig. 2) has been placed in its right hand seat, and, having a limited range of motion, it rests at a point from which it is drawn with the slightest impulse towards its left hand seat. Now, while steam is entering the left-hand chamber with a steady, uniform flow, this little ball will keep the position shown, because the pressure of the steam from above tends to hold it against each seat alike, consequently it remains in whichever seat it is first inclined towards; but as soon as the sudden collapse of the steam by condensation takes place the consequent rush of steam to fill the vacuum instantly unbalances the equilibrium of forces which held the little ball, and it is instantly drawn from its right-hand seat into its left-hand one, and stops the further entrance of steam into the left-hand chamber. The steam current then enters the right-hand chamber and expels the water therefrom also, in the same manner as described for the left-hand chamber. But while the water is being expelled from the right-hand chamber, the vacuum just produced in the left-hand one causes it to immediately fill with water through the induction pipe, and past the ball-valve near the bottom of the chamber, which freely rolls up and out of its seat, permitting the water to freely enter, but instantly falls back to its seat when the chamber is full, prevents the return of the water, and is then ready for the succeeding round of operation as first above particularly described.

The ball-valve in the discharge chamber simply vibrates between its two seats, in a manner similar to the steam-ball before described, and by its alternation simply checks the back flow of the water after it has been expelled from the chambers. The same vacuum impulse which draws the steam-ball towards the upper entrance of the chamber, also draws the ball in the discharge chamber towards its seat, and thereby always leaves the passage for the water from the emptying chamber open. The intermediate chamber shown at B connects directly with the suction pipe, and contains air in its upper portion, which serves to cushion the ramming action of the water as it rushes up the suction-pipe to fill the vacuum alternately formed in the chambers respectively. A small air check-valve is screwed into this vacuum chamber, which lifts when a partial vacuum is produced in the chamber, and allows a little air to enter, but closes against its return. It will open at each pulsation, and its lift; consequently the quantity of air entering the chamber may be regulated by a little milled nut, the operation of which will be readily understood.

Owing to the peculiar form of the large chambers, the steam on its entrance comes in contact with a small surface of water only, which gradually expands as the surface is quietly depressed, thus securing freedom from agitation of water surface, and thereby condensation of the steam, until the discharging outlet is reached by the steam, when instantly the agitation necessary to accomplish the condensation of the steam takes place, and the vacuum is produced as above described. This simple combination of rigid castings, with these four balls, gives all the elements of a double-acting steam pump, having two chambers, which fill and empty alternately, thus drawing and forcing water at the same time. The conditions upon which the proper action of the pulsometer depends are similar, in all essential particulars, to those which pertain to the management of the ordinary double-acting steam pump. It may be placed above the source of supply, a height due a vacuum, and the height to which it will elevate the water is limited only by the presence of the steam in the boiler operating it.

Of the advantages claimed for this device by its inventor, C. Henry Hall, of New York, and the uses to which it may be advantageously put, the following statement will suffice:

It is claimed to be excellently adapted for pumping water from mines, inasmuch as it is not liable to derangement or injury from grit, sand, &c.; also, that it has proved itself of great value in digging foundations and excavating where quicksand or mud occur, pumping the water charged with such impurity without damage; also, that it is adapted for irrigating lands, draining swamps, &c., filling tanks at railroad stations, and for service on shipboard either as a bilge-pump, deck-pump, or fire extinguisher. In brief, it is claimed that the apparatus may be economically and satisfactorily employed under all conditions where water, free from or charged with sediment, is to be pumped, and that the water may be raised to a great perpendicular height, with a comparatively low pressure of steam, by placing a number of the pulsometers above each other, and connecting the discharge pipe of each with the suction pipe of the one above.

An Automatic Railway.—At the stated meeting of the Institute, held Nov. 19th, 1873, Mr. C. W. Hunt, of New York, read the following paper on an automatic railway of his own invention:

The importance of moving and storing coal, ore, or other bulky materials, cheaply, is so generally recognized that the advantages of this railway will be readily appreciated.

The automatic railway is not an improvement or modification of any existing railway, but differs from all, in using the momentum of the loaded car to return the empty car to the loading station.

A large portion of the coal and ore mined is carried the whole or a part of the distance from the mines to the consumer in boats, and when unloaded must, in most cases, be carried back from the bank of the river or canal to the bins or sheds for storage. This is the special function of the automatic railway.

The chief peculiarity of this railway consists in the utilization of the momentum acquired by a loaded car descending an inclined track to return the empty car to the place whence it started. Its advantages are that, without steam or horse power,—

1st, it has three times the capacity of any other method of handling coal or ore.

2d, the running expenses are the wages of one man only.

3d, simplicity.

In unloading coal from boats, it is hoisted by any method and dumped in the car. When filled, the car is started and runs down the inclined track by the force of gravity, deposits its load and is rereturned to the loading point by a weight which the car had raised before the load was discharged.

After loading, the workman starts the car, but does not accompany it down the inclined track; in thirty seconds it has deposited its load in the bins, 150 feet distant, returned and ready for another load. If the car is loaded in 30 seconds, it will be handling coal at the rate of 60 tons per hour, or 600 tons per day, which is about double the amount that can be shoveled and hoisted. The railway is in operation only 30 seconds to each ton; whatever time is taken beyond this is for loading. The whole length of the road is available for storage, as the car dumps the load at any point desired.

Although the capacity of the railway is three times that of any other, yet the operating expenses are far less, as only one man is required in any case. Manufacturers or coal dealers, piling their coal on the end of the dock, require one man on the pile to dump the buckets as hoisted; by using the automatic railway the coal can be carried to any part of the track without any extra expense whatever, as the same man who dumps the buckets also attends the railway. It will cost no more to store coal in the bins 200 feet from the wharf than to dump it on the end of the dock.

This railway is so simple and automatic that an ordinary laborer

only is required. There is but one track, 18 inches gauge, and one car; there are no loose pieces to get lost or stolen; after using, nothing to take care of or put away; the car is left just as used, and is ready for use at any time.

The reacting weight can be placed at any part of the track, and be boxed in, as it requires no attention whatever.

The car used dumps the load at any part of the track required. The bottom is inclined each way from the centre, and the sides hinged near the top of the car. The sides are fastened, not to the car, but to each other, holding the car between them, making it impossible for one side to open and not the other. When the sides are opened the coal runs out on either side of the track.

The car is built in the best manner, and weighs 500 lbs. It has 15-inch wheels, Jones & Laughlan's "cold-rolled piston-rod" axles rubber springs, self-adjusting anti-friction bearings and iron-lined bottom. The rope used is Garnock, Bibby & Co. steel; the sheaves have patent roller bearings, requiring no oil. No effort or expense is spared to make this railway the most perfect as well as the most economical railway for yard purposes in existence.

A Combined Heating and Ventilating Apparatus. (Patent of Geo. R. Barker.)—In vol. lxv of the "Journal," page 292, there was illustrated and described a device of this kind, invented by Mr. Geo. R. Barker, a member of the Institute. The essential features of the device consist in the fact that the heating and ventilation are both effected through the same flue, by the insertion therein of a supplementary flue or pipe, dividing the register face into two halves, through the upper one of which the fresh heated air from the furnaces enters the room, while the vitiated and cooled air is drawn out of the room through the lower partition. The apparatus, above described in brief, is designed for the vertical registers located about the sides of the apartments.

The arrangement herewith illustrated is a modified form of the first described apparatus by which the same is made applicable to the floor of an apartment in such a manner that, while the hot fresh air is passing up through the floor, the vitiated air is caused to flow down through adjustable openings, situated immediately surrounding the place of entrance for the heated air, into a suitable conduit pipe leading to the chimney or other flue below the floor.

Figure 1 gives a vertical section of the arrangement. The heated air passes upwards from the furnace through the hot-air pipe, C, which

is surrounded by a casing, A, extending some distance beneath the floor, leaving an annular space, A A, about the hot-air pipe, which serves as the egress space for the vitiated or cold air.

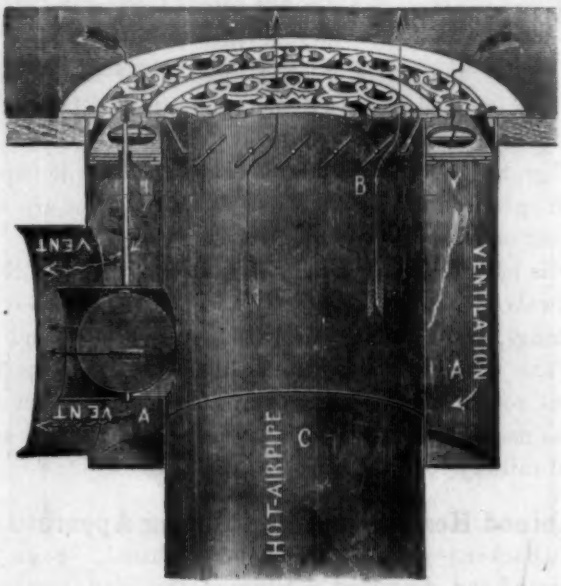


Fig. 1.

The register face is also of annular construction, to correspond with the functions of the several parts of the contrivance over which it is placed. (The figure 2 shows its construction). The openings governing both the ingress and egress passages are controlled by the usual mechanism of an adjustable grating.

The vitiated air which is drawn from the room downward into the annular space A, passes off, in a lateral direction, into a pipe communicating with the ventilating flue.

In the device described in the May number of the "Journal," before referred to, there was an adjustable valve in the upper part of the hot-air pipe, whereby either a portion or all of the heated air rising therein may be discharged into the vitiated air-flue, the object of said attachment being to afford a means of relieving a room whenever, as for example when crowded, it shall become excessively hot, or the air very impure.

The same result is provided for, in the modified arrangement here

described, by inserting into the side of the hot-air flue, C, a short pipe (see figure 1), which is made to extend some distance into the conduit pipe. This is fitted with an adjustable valve, whereby the hot entering air may be turned either entirely or in part into the vitiated air-flue whenever it is desired to regulate the warmth of the room above the floor.

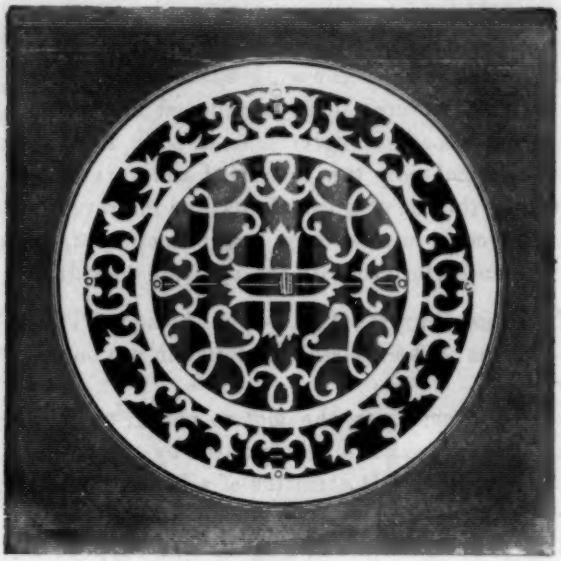


Fig. 2.

The device is, of course, equally applicable to any form of heating apparatus elevated above the floor, with the same merits of simplicity and efficiency possessed by the original apparatus before alluded to.

The Hoosac Tunnel.—The approaching completion of this important undertaking affords at present a theme of comment on the part of the technical press of the country. It is now announced from reliable sources that the work, including the laying of the permanent way, will be fully completed by the 1st of July, 1874. From the monthly reports of progress furnished by the contractors, which are from time to time published, the work of pushing forward the headings has progressed favorably and uninterruptedly for some time, there remaining on the first of November only about one hundred feet of rock to be pierced. Before the close of the month, therefore, there is every probability, unless some unforeseen accident intervenes

to interrupt the average progress of the tunnelling work, that the two headings will meet.*

From a contemporary† we take the following comments:

The Hoosac Tunnel is four and three-quarters miles long, twenty-four feet wide by twenty-six feet in height. The rock through which it has been pierced is of a very indurate character; so much so as to render the work considerably more difficult than that of the Mont Cenis Tunnel, which is, however, seven miles long. The central shaft is 1030 feet deep. The work was commenced in 1850, and, after having been several times abandoned and recommenced, the present contractor made an agreement, in 1869, to complete it within five years. Undoubtedly the success of the work has been greatly dependent upon the use of steam drills and improved blasting explosives; nitro-glycerin has also been largely employed, and most of the drilling has been performed with the Burleigh rock-drill.

The Fireless Locomotive.—The Chicago "Times" gives the following account of the fireless locomotive in use on the tramways of that city:

In front of the cars was the motive power, contained in a small, compact and neat locomotive, manipulated by an engineer. This was the fireless locomotive. It consisted of a boiler, 8 feet long by 3 feet in diameter, and the usual machinery on a small scale. There was no fuel, no fire, no fireman. The steam was supplied for the round trip of six miles before starting. At the depot was a supply boiler, 16 feet by 3 feet, in which steam was generated until 200 lbs. pressure was indicated by the steam gauge. The locomotive boiler was three-fourths full of cold water. Instead of boiling this by means of a fire, and raising the pressure to a required height, the steam was introduced from the supply boiler through an iron tube. The iron tube was connected with the locomotive boiler, the latter running under the water, along the bottom of the boiler, and letting out the steam as it was freed from the supply boiler into the locomotive boiler. This steam, rising through the cold water, permeated it, and quickly raised its pressure to 170 lbs. With this supply of steam the locomotive started, drawing a heavy four-horse car, over three miles, to Thirty-fifth street in ten minutes.

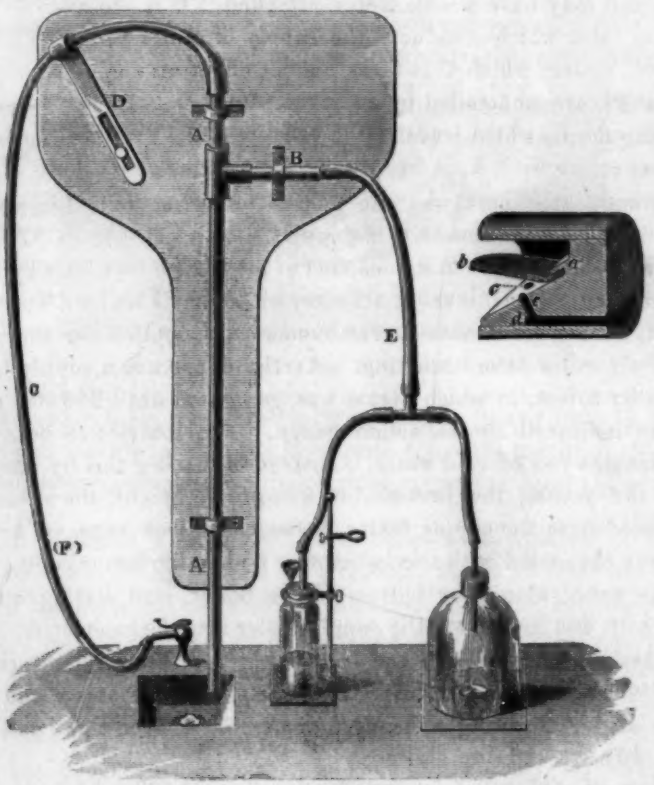
The amount of steam consumed represented 80 lbs. pressure, locomotive starting back with 90 lbs. remaining. When the starting point

*The headings met on Nov. 24th, and the tunnelling work is complete.

† Am. Artisan.

was reached there were 57 lbs. of steam in the boiler, the pressure being reduced only 33 lbs. in return trip, which was a down grade. It must be borne in mind that there was a large car, heavily laden, making 18 miles per hour. The experiment proved conclusively that, as a substitute for dummy engines, the fireless locomotive is, beyond question, a success. No fire or fireman are necessary, very little steam escapes, and the locomotive, not being one-half the size of the clumsy dummy engine, does not frighten horses and endanger the public safety.

On a Modification of Jagn's Filter Pump.—By Prof. A. E. Foote.—The general introduction of the Sprengel vacuum pump, since its modification by Bunsen, has been somewhat interfered with



by the difficulty, in some cases, of securing the required fall of water. The pulsating pump of Jagn, to a great extent, obviated this difficulty, rendering it possible, from a fall of from four to five feet, to

produce a tolerably good vacuum. Many inconveniences, however, have been experienced by those adopting the device indicated by Jagn and others, the most troublesome defect residing in the caoutchouc valve, which very soon becomes imperfect or inoperative.

The accompanying illustration represents a form of construction devised by Prof. A. E. Foote, and is fully described in the Am. Jour. of Science (November, 1873). The device is stated to be simple in construction, to be free from the objections attaching to those above named and to give very good results. The following is a condensed description of the apparatus: A, A is a tube about four feet long, and from three eighths to one inch in diameter. To the side of this is attached an arm B by a T coupling. B is from four to eight inches long, and may have a manometer attached. C is the caoutchouc vibrating tube, which conducts the supply of water to A. The upper part of A, over which C is thrust, is cut off at an angle of 40°. The vibrations are controlled by a movable arm D. To B is attached a rubber tube E, which leads to the vacuum flask. Within B, and near its connection with A, is fixed with cement the valve shown in fig. 2, constructed as follows: A cylindrical metal plug, about one inch long, and of such dimensions as to slip easily within the tube B, is cut away at one end (as shown in fig. 2, where it is represented in section with a portion of tube B) leaving a tongue of metal. This tongue is driven down upon a flap of sheet caoutchouc about one millimeter in thickness b, which is thus held upon the bevel of the plug, and covers the two channels c c, one of which is seen in section. These channels communicate with passage d, made by filing away the metal of the plug tangentially (see cut). The caoutchouc flap is represented as lifted away from the face of the plug, in order to show the orifices which it closes when the water current in the tube B is checked. These holes, in order to be perfectly closed by the flap, must be at least one-sixteenth of an inch in diameter. The sheet caoutchouc should be thin as possible, to insure perfect action. This plug must be hermetically cemented with the tubes. A clamp placed upon E, and used to retain the vacuum, may also be made to regulate the rapidity of exhaustion, but this may be accomplished more conveniently by means of a stop-cock, F, inserted in C, which regulates the flow of water; or, by means of a "globe-valve" placed in the supply pipe. The angle at which A is cut off at the top is also important. If not just right the vibrations of the caoutchouc tubes are not perfect.

The apparatus above described can be constructed cheaply by any plumber or gas fitter, and is said to work very efficiently.

The Behavior of Metals under Stress.—Interesting and important results have been obtained in the course of the investigations in progress at the Stevens Institute of Technology upon the behavior of metals under stress.

The testing machine invented and designed by Professor Thurston, with its automatic registry, was described in our issue of April last, and its peculiar value in detecting all phenomena of stress, and in affording a reliable and permanent record, is shown by inspection of the curves given in the plate accompanying that article.

The apparatus was exhibited at the last meeting of the National Academy of Science, which was held at the Stevens Institute, and its capability of revealing the action of molecular forces under stress was illustrated. At the close of the session a test piece was left in the machine, strained far beyond its limit of elasticity, to determine, if possible, the existence or non-existence of "viscosity" in the metals.

After twenty-four hours, there appearing no evidence of further yielding, the distorting force was increased, when the discovery was made that the resisting power of the specimen had actually become greater during the period of rest under strain, and the pencil, instead of descending, rose until it indicated an increase of about twenty per cent. in the strength of the sample, and it then traced a path parallel with but above that of the previous day.

Repeated experiments confirmed this remarkable and important deduction of the experimenter:

That metal strained so far as to take a permanent set, and left under the stress producing it, gains in power of resistance up to a limit of time, which in these experiments was about seventy-two hours, and to a limit of increase which has a value, in the best iron, of about 20 per cent., where the applied force is eighty per cent. of the ultimate breaking force.

In other words, the metal developes nearly or quite its maximum strength long before reaching the point of rupture, instead of at that point, as when broken at once by a continually increasing stress.

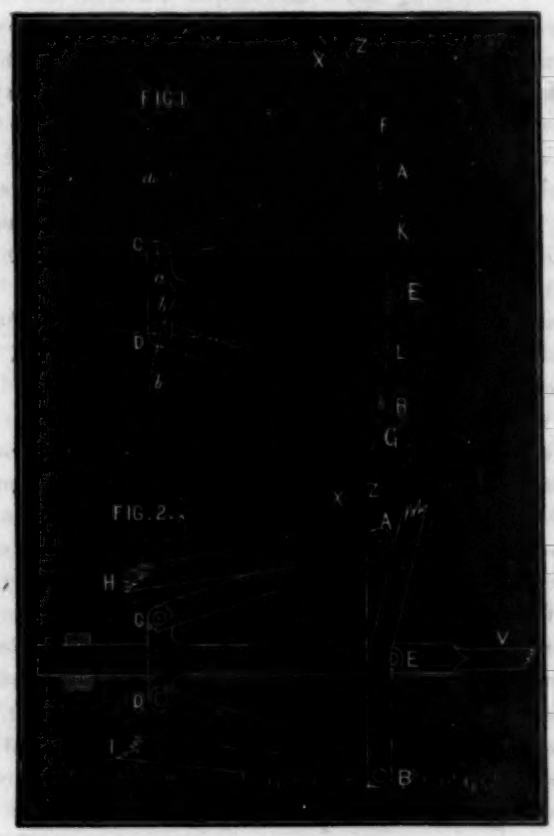
This discovery was announced by Professor Thurston at the annual meeting of the American Society of Civil Engineers, November 5th, and the possible bearing of the earlier experiments of the Committee

of the Franklin Institute on "Thermo-Tension," and of the well-known property of the increasing portative force of magnets under strain, as illustrations of related phenomena, were alluded to.

The existence of this property had already been suspected, but it is evident that it could only be conclusively proven by apparatus embodying the principles of that used in this research.

Manufacturers are forwarding for examination samples of metals of all kinds and qualities, and we are able to promise the account of some very interesting results and precise figures and *fac similes* of the diagrams obtained.

A Substitute for Links or Link Motions.—By HUGO BILGRAM.—By the arrangement of levers represented in Fig. 1 the end, E, of the T-shaped middle piece is guided in a curve, X X, which,



between F and G, so nearly coincides with the arc of a circle, Z Z, that practically it cannot be distinguished from the latter. The rods A C and B D form the guides of two points of the middle piece, and have their respective fulcrums in A and B, as the engraving shows. For its remarkable property this combination may be utilized to substitute the links of reversible engines that are exposed to destructive influences; for instance, of crane engines in foundries, where the sand suspended in the surrounding air causes a considerable wear of the sliding parts of the engines, and necessitates frequent repairs. It may also be applied on cheap reversible engines, especially if their manufacturers are not provided with suitable facilities to give the link its proper curvature.

In Fig. 2, H and I represent the excentric rods of a Stephenson's link motion, in which the link is substituted in this manner. A plain connecting piece, A B, takes the place of the link, and may be suspended in the usual way. To the ends of the excentric rods are also attached the two guiding rods, A C and B D, to which the T-shaped middle piece is fastened by the pins C and D, the end of which, E, moves directly the valve stem, V, or the rocker. The point E being guided in relation to A B as though it was moving in a slot, conform to Z Z, this arrangement produces the same motion as the ordinary link. By the way of suspension, the corrections of the irregularities between fore and back stroke can be accomplished in this modified link motion as well as in the original one.

A rule for the choice of proper dimensions can be only empirical. A good result may be obtained if the rods A C and B D are made equal to, or at least not much shorter than, the link A B. The dimensions of the T-shaped lever are easily found by first sweeping the circle Z Z of the proper radius, then drawing the chord A B of a length equal to that of the link, and sweeping two arcs, *a a* and *b b*, from A and B, with radii equal to the length of the guiding rods. If, now, the chords A E and B E (E being the vertex of arc Z Z) are perpendicularly divided in two equal parts by the lines C K and D L, then the respective points of intersection, C and D, with the arcs *a a* and *b b*, together with the vertex E, represent the three characteristic joint centers of the middle piece.

The application of this arrangement is not restricted to Stephenson's link motion only, as it may be applied to any other expansion gearing in which a link is used.

A New Process for the Manufacture of Soda.—The well-known, and for nearly a century almost exclusively practiced, process of Leblanc for the manufacture of soda from common salt, has at length, if we may rely upon the opinion expressed by the chemical section of the International Jury at the recent Vienna Exposition, found a formidable rival in a new process, which has been called the Ammonia process.

A similar jury at the Paris Exposition, six years ago, announced the opinion that the process of Leblanc wonld hold the field for a long time to come; yet in that brief space of time the new process, then in its infancy, has grown into a flourishing industry, not only successfully competing with the Leblanc, but threatening it, in the immediate future, with comparative extinction.

The process, which presents so revolutionary an aspect, is not new in point of discovery, having been patented in Great Britain over thirty years ago, but from several difficulties, of which the then comparatively moderate demand for soda, the impossibility of obtaining ammonia in large quantity and cheaply, and the inefficient state of that branch of machine building for supplying the necessary plant, were most inseparable, the new invention was abandoned. Subsequent to this early attempt, the ammonia process was several times resuscitated in various European countries, but as often abandoned. Now, however, that the difficulties in its development are removed, it has lately started into life, and developed to an extent surprising even to those fully aware of the possibilities inherent in it.

The new process is based upon the reaction of the bi-carbonate of ammonia with a strong solution of common salt. The result of this interaction is the precipitation of most of the sodium as bi-carbonate, while the resulting chloride of ammonium remains in solution. From this chloride the ammonia is expelled, with the aid of quick-lime, to be employed in a second operation. The bi-carbonate of soda, as produced, is converted to the simple carbonate (the soda of commerce) by simply heating, and the equivalent of carbonic acid so driven off is led into the ammonia to convert it again into the bi-carbonate, thus making the process a continuous one.

These are the general features of the new soda process, which has suddenly grown into such importance. Many minor details are as yet unknown, though enough is known to make it evident that it possesses several striking advantages over that of Leblanc. The most obvious of these resides in the fact that, with the new process,

the conversion of the salt into soda is direct, while with the Leblanc, as is well known, the conversion is effected indirectly by several intermediate steps. Again, none of the heavy metals are precipitated from the brine, and the product is said to be absolutely free from sulphur compounds—a source of great annoyance with the old method. Lastly, but not least, the plant is simple and comparatively inexpensive, and no noxious gases or waste products are produced. The chloride of calcium, the only waste product which the new process entails, is inoffensive, and, from indications, the demand for it in several new and growing industries will absorb much of what may be supplied from this source.

It is stated upon reliable authority that there are large soda works in England, Hungary, Switzerland, Westphalia, Thuringia, Baden and elsewhere, operating the new ammonia process, the daily production of some of which amounts to as much as fifteen tons.

It is yet too soon to speculate upon the influence which the growth of the new manufacture will exert upon many branches of chemical and related industries; but from the leading position occupied by soda in these departments and the inter-dependence in production and consumption of this and many other chemical substances largely employed in the arts, such as sulphuric acid, hydrochloric acid, chloride of lime, etc., indirectly affectingthese arts themselves, this influence must be both wide-spread and important.

Peruvian Nitrate of Soda.—It is said that the Nitrate of Soda trade has wonderfully increased within the last twenty-five years. In 1848, three vessels were sufficient to supply the demand, while now one hundred vessels are waiting for cargoes at the port of Iquique. A railway now connects the port with the saltpetre districts of the interior, and through its entire length is surrounded by manufactories.

Thirty-one establishments, supplied with excellent machinery, are now in operation, and capable of producing 1250 tons per diem. Twenty-one additional establishments are being constructed, so that, in a short time, it is estimated, the production will amount to 19,000 tons a day, or to no less than 5,750,000 tons a year.

Civil and Mechanical Engineering.

THE PRINCIPLES OF SHOP MANIPULATION FOR ENGINEERING APPRENTICES.

By J. Richards, Mechanical Engineer.

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(Continued from page 327.)

The Objects of Mechanical Industry.

Mechanical engineering, like every other pursuit, is directed to the accumulation of wealth; and, as the attainment of any purpose is more surely achieved by keeping that purpose continually in view, there will be no harm, and perhaps no little gain, derived by an apprentice considering at the beginning the main object to which his efforts will be directed after learning his profession or trade.

So far as an abstract principle of motives, it is of course useless to consider this subject in connection with engineering operations or shop manipulation; but the subject of commercial gain has a practical application, to be followed throughout the whole system of industrial pursuits, and is as proper to be considered in connection with machine manufacturing as mechanical principles or the functions and objects of machines.

"Cost" is the element that continually modifies or improves manufacturing processes, determines the success of every establishment, is continually present in making drawings, patterns, forgings and castings.

Machines are constructed because of the difference between what they cost and what they sell for—between the manufacturing cost and their market value when they are completed.

It seems hard to deprive engineering pursuits of the romance that is often attached to the business, and bring it down to a matter of commercial gain, but it is best to deal with facts, especially when such facts have an immediate bearing upon the object in view.

There is no intention in these remarks of disparaging the works of many noble men, who have given their means, their time, and sometimes their lives, to the advancement of scientific truths, without hope or desire of any other reward than the satisfaction of having performed a duty.

The following propositions will place this subject of aims and objects before the reader in the sense here intended:

First. The object of engineering pursuits is commercial gain, the profits derived from the planning and construction of machinery.

Second. The gain so derived is as the difference between the cost of constructing machinery, and the market value of the machinery produced.

Third. The difference between what it costs to plan and construct a machine and what it will sell for, is generally as the engineering knowledge and skill that is brought to bear in producing the machine.

This last sentence brings the matter into a tangible form, and indicates what the subject of gain should have to do with what an apprentice is to learn of machine construction.

Success in an engineering enterprise may be temporarily achieved by illegitimate means, such as misrepresentation as to the capacity and quality of what is produced, the use of cheap or improper material, or by copying the plans of others to avoid the expense of engineering service, or from want of engineering ability; but, in the end, the permanent success of such a business must rest upon the knowledge and skill that is connected with it.

By examining into the facts, the apprentice will find that all truly successful establishments have been founded and built upon the mechanical abilities of some person or persons that formed a base upon which the business was reared, and that this is the essential element that must in the end lead to permanent success.

The material and the labor which make up the first cost of machines is, taking an average of various classes, nearly equally divided; labor being in excess for the finer class of machinery, and the material in excess for the coarser kinds of work.

The material is presumed to be purchased at the same rates by those that are well skilled as by those of inferior skill, so that the difference in first or manufacturing cost is determined by skill exclusively.

This skill consists in preparing plans and in various processes for connecting and shaping the material, which will be noticed in their regular order.

The amount of labor and consequently the cost of machinery produced is as the number of these processes and the time consumed in each.

The business of the mechanical engineer is to reduce the number of these processes or operations, and to shorten the time in which they may be performed.

A careful study of shop processes or operations, including designing, draughting, moulding, forging and fitting, is the secret of success in engineering practice, or in the management of manufactures.

The advantages of an economical design, or the most carefully prepared drawings, are easily neutralized and lost by careless or improper manipulation in the workshop; an incompetent manager may waste more pounds in shop processes, than the commercial department can save pence in buying and selling.

This importance of shop processes in machine construction is realized by proprietors, but not generally understood in all of its bearings; yet the apprentice may notice the continual effort that is made to augment production in engineering works, which is the same thing as shortening the processes.

By reasoning in this manner the apprentice will form true standards by which to judge of plans and processes that he is brought in contact with.

A machine may be mechanically perfect, arranged with symmetry, true proportions and correct movements; but if such a machine has not commercial value, and is not applicable to a useful purpose, it is as much a failure as though it were mechanically inoperative. In fact, this consideration of cost and commercial value must be continually present, and a mechanical education that has not furnished true conceptions of the relations between commercial cost and mechanical excellence, will fall short of achieving the objects for which such an education is undertaken.

On the Nature of Machinery.

Machines may be defined in general as agents for transmitting and applying power, or motion and force, which constitutes power.

By machinery the natural forces are utilized, and directed to the performance of operations where human strength is insufficient, or when natural force is cheaper, and when the rate of movement exceeds what the hands can perform.

The term "agent" applied to machines conveys a true idea of their nature and functions. Machines do not create power or consume power, but only transmit or apply it; and it is only by conceiving of power as a constant element, independent of all kinds of machinery,

that the learner can have a true conception of the nature of machines. When once there is in the mind a fixed conception of power, dissociated from every kind of mechanism, there is laid a solid foundation on which a knowledge of machines and mechanics may be built up, but without this conception correctly fixed in the mind, it is not only impossible to appreciate the true nature of machines, but difficult to understand even the most simple principles in mechanism.

To believe a fact is not to learn it, in the sense that this term may be applied to mechanical knowledge; to believe a proposition is not to have a conviction of its truth, and what is meant by learning mechanical truths is to have them so firmly fixed in the mind that they will involuntarily arise to qualify everything met with that involves mechanical movement.

An apprentice or student that in his younger days has had the misfortune to confound power with machinery for transmitting it, as taught in school-books on mechanical philosophy, will find these impressions remain in his mind for years, even after he has become acquainted with the true principles of mechanism. For this reason the apprentice is urged to start rightly, first acquiring a clear and fixed conception of power, and next of the nature and classification of machines, for without the first he cannot have the second.

I am well aware of the difficulty that must be encountered in attempting to learn the nature and classification of machines without the aid that may be derived from a knowledge of their practical application; but to learn such practical application first is certainly to commence wrong, because of the waste of time and effort that is required by such a course; and, while it may be difficult to form such clear conceptions of machines by studying their nature and general principles in advance of being acquainted with their application, it is by no means impossible to do so.

Machinery is divided into four classes, each constituting a division, that is clearly defined by the functions it performs, as follows:

First. Motive machinery for utilizing natural forces.

Second. Machinery for transmitting and distributing power.

Third. Machinery for applying power.

Fourth. Machinery for transportation.

Or, more briefly stated: Motive machinery, machinery of transmission, machinery of application and machinery of transportation.

I will now proceed to consider these divisions of machinery with a view to making the classification more clear, and shall revert briefly

to the principles of operation in each division; and as this dissertation will form a kind of base upon which the practical part of the treatise will in a measure rest, it is trusted that the reader will not only carefully consider each proposition that is laid down, but will add others from his own deductions as he goes along.

Motive Machinery.

In this class belongs steam engines, caloric or air engines, water wheels or water engines, and wind wheels or pneumatic engines. These four types comprehend the motive power, as it is termed, of the present day.

In considering these engines for motive power in a way to best comprehend their nature, the first view to be taken is that they are all directed to the same end, and all deal with the same power, and, if possible, to avoid the impression of their being different kinds of power, as the terms usually employed seem to imply. We speak of steam power, water power or wind power; but power is the same from whatever source derived, and these distinctions merely indicate different natural sources from which power is derived.

Primarily, power is the product of heat, and wherever force and motion exist, they can be traced to heat as the generating element, whether the medium through which the power is obtained be by the expansion of water or gases, the gravity of water or the force of wind, heat will always be found as the prime source.

As steam engines constitute a great share of machinery that is commonly met with, and as a class of machinery naturally engrosses attention in proportion to its importance, the study of mechanics generally begins with steam machinery. The subject of steam power, aside from its mechanical consideration, is one that may afford many useful lessons, by tracing its history and its influence, not only upon mechanical industry, but upon human interests generally. The subject is often hinted at, and its importance conceded, but no one has from statistical and other sources ventured to estimate in a methodical way the changes that can be traced directly and indirectly to steam power.

The steam engine is the most important and in America and England best known among motive agents. The importance of steam contrasted with other sources of motive power is not due to the cheapness of cost at which power is in this way obtained, but for the reasons that amount of power produced can be governed at will, the power can be

produced without reference to local conditions, and in any place; the machinery can with its fuel and water, the elements of its power, be transported from place to place, as in the case of machinery for transporting, the locomotive not only supplying power for its own transit, but carrying besides vast loads of merchandise or travel. For manufacturing processes the main advantage of steam power rests in the fact that power can be taken to the material, and beside other advantages gained thereby, is the difference in weight and cost between transporting the manufactured product and the raw material. In the case of iron manufacture, for example, it would cost ten times as much to transport the ore and the fuel used in smelting as it does to transport the manufactured iron; steam power saves this difference, and without steam power our present iron traffic would be impossible.

The steam engine, in the sense in which the term is employed, means not only steam using machinery, but steam generating machinery or plant; it includes the engine proper, with the boiler, mechanism for feeding water to the boiler, also for governing speed, with indicators and other details.

The apprentice must guard against the too common impression that the engine, cylinder, piston, valves, and so on, are the main parts of steam machinery, and that the boiler and furnace are only auxiliaries. The boiler is the soul of the whole, the part where the power is generated, the engine being merely an agent for transmitting power from the boiler to the work that is to be performed. This conclusion would, of course, be reached by any one in reasoning about the matter and following it to a conclusion, but the fact should be fixed in the mind as a principle of steam power.

When we look at a steam engine there are certain impressions conveyed to the mind, and by these impressions we are governed in a train of reflection that follows. We can conceive of the cylinder and its details as a complete machine with independent functions, or we can conceive of it as a mechanical device for transmitting force from the boiler, and this conception may be independent of, or even contrary to, specific knowledge that we at the same time possess; hence the importance of starting with a correct idea of the boiler being, as we may say, the base of steam machinery.

As reading books of fiction sometimes expands the mind and enables it to grasp great practical truths, so may a study of theoretical principles enable us to comprehend the simplest forms of mechanism. Even Humboldt and Agassiz resorted to imaginative speculations as a means of expanding their minds.

In no other branch of machinery has so much research and experiment been made during eighty years past as in steam machinery, and, strange to say, the greater part of this research has been directed to the details of engines, and yet there has been no improvement made during the time that has effected any considerable saving of heat or expense. The steam engines of fifty years ago, considered as steam using machines, utilized nearly the same proportion of the energy or power developed by the boiler as the most improved engines of modern construction—a fact that in itself indicates that the engine is not the vital part of steam machinery. There is not the least doubt that if the efforts to improve the steam engine had been mainly directed to economizing heat and increasing the evaporative power of boilers, much more would have been accomplished.

This remark, however, does not apply to the present day, when the principles of steam power are well understood, and when heat is recognized as the proper element to deal with in attempts to economize in the cost of power.

There is, of course, various degrees of economy in steam using as well as in steam generating machinery, but so long as the best steam machinery does not utilize but one-tenth or one-twelfth of the heat that is represented in the fuel burned, there need be no question as to the point where improvements in such machinery should begin.

With these remarks as to steam power in general, I will proceed to consider the principles upon which steam engines operate.

A cubic inch of water, by taking up a given amount of heat, is expanded to more than five hundred cubic inches of steam at a pressure of forty-five pounds to the square inch.

This extraordinary expansion, if performed in a close vessel, would exert a power five hundred times as great as would be required to force the same quantity of water into the vessel against this expansive pressure; in other words, the volume of the water when put into the vessel would be but one five-hundredth part of its volume when it is allowed to escape, and this expansion, when confined in a steam boiler, exerts the force that we term steam power.

This force or power is through the means of the engine communicated and applied to different kinds of work where force and movement are required. The water, like the engine and the boiler, is merely an agent through which the energy or power of heat is applied.

This brings us to the original proposition that power is heat, and heat is power, the two being convertible and, according to modern science, indestructible; so that the power, when used, must give off its mechanical equivalent of heat, or heat, when applied, develop its equivalent in power. If the whole amount of heat represented in the fuel used for a steam engine could be utilized, the effect would be, as before stated, from ten to fifteen times as great as it is in actual practice, from which it must be inferred that a steam engine is a very imperfect machine for utilizing heat.

This loss arises from the fact that the heat cannot be directly nor fully communicated to the water.

To store up and retain the water after it is expanded into steam, a strong vessel, which we term a boiler, is required, and all the heat that is imparted to the water has to pass through the plates of this boiler, which stand as a wall between the heat and its work.

Reasons for the extended and general use of steam as a power, besides those already named, are to be found in the fact that n other available element or substance can be expanded to a given degree, at so small a cost as water; and in the fact that its temperature will not rise to a point that will destroy the machinery for generating and using steam, and, further, in the very important property of lubrication that steam has in protecting the frictional surfaces of pistons and valves, which it is impossible to keep oiled because of their inaccessibility and the high temperature.

To summarize, we have the following propositions relating to steam machinery.

The steam engine is an agent for utilizing the power of heat and applying it to useful purposes.

The power of the heat is obtained by expanding water in a confining vessel, and employing the force exerted by the pressure thus obtained.

The power obtained is as the difference of volume between the feed water when forced into the boiler, and the volume of the steam that is drawn from the boiler, or as the amount of heat taken up by the water.

The heat that may be utilized is what will pass through plates of the boiler, and but a small share of what the fuel produces.

The boiler is the main part, where the power is generated, and the engine is but an agent for transmitting this power to the work to be performed.

An engine, when well constructed, transmits the power generated by the boiler with but little loss, but the best constructed boiler, as said, can only utilize but a small portion of the heat represented in the fuel.

The loss of power due to its transmission through an engine is from radiation of heat, the escape of steam at pressure after acting on the piston, and the friction of moving parts.

By condensing the steam before it leaves the engine, so that it is returned to the air as water, and of the same volume as when it entered the boiler, there is a saving equal to the pressure of the atmosphere.

These propositions relating to steam engines, if remembered and studied by apprentices in connection with steam machinery, will lead to a reasoning about the principles, as well as of the mechanism, and render the nature of steam power more easily understood.

Engines operating by means of hot air, called caloric engines, and engines operated by gas, or explosive substances, all act substantially upon the same general principles as the steam engine; the greatest distinction being between the generation of heat by the combustion of fuel and by chemical action.

With the exception of caloric or air engines, however, there is but a limited use of any but steam engines for motive power, and it may be safely assumed that the learner who has mastered the general principles of the steam engine will find no trouble in analyzing and understanding any similar machinery acting from expansion due to heat, whether air, gas or explosive agents be employed. This method of treating the subject of motive engines will no doubt be presenting it in a new way, but it is merely beginning at an unusual place, nothing more. And the learner who commences with first principles, instead of pistons, valves, connections, and bearings, will find in the end that he has not only adopted the true plan, but the shortest one to understanding steam and other expansive engines.

Water Power.

Water-wheels, next to steam engines, are the most common motive agents. For centuries water-wheels remained without much improvement or change, down to the period of Turbine water-wheels, when it was discovered that instead of being a very simple matter, the application of water power was found to involve some very intricate conditions, and gave rise to many problems of scientific interest, that in the end produced the modern Turbine wheels.

A modern Turbine water-wheel, of the best construction, operating under favorable conditions, gives a per centage of the power of the water that almost reaches the theoretical coefficient of its gravity, and it may be assumed that there will in the future be but little improvement made in such water-wheels except in the way of simplifying and cheapening their construction. In fact, there is no other class of machines that seems to have reached the same state of improvement as water-wheels, nor any other class of machinery that is constructed with the same uniformity of design and arrangement in different countries and by different makers.

Every one remembers the classification of water-wheels met with in the older school-books on natural philosophy, where we are informed that there are three kinds of wheels, as there were "three kinds of levers," namely, overshot, undershot, and breast wheels, with a brief notice of Barker's mill, than ran apparently without any good reason for so doing.

Without finding fault with this plan of describing water-power, farther than to say that a little explanation of the principles by which power is derived from the water would have been more useful, I will venture upon a different classification of water-wheels, that is more in accord with modern practice, and without reference to the special mechanism of the different wheels, except when unavoidable.

Water-wheels can be divided into four general types:

First. Gravity wheels, acting directly from the weight of the water which is loaded upon one side of a wheel revolving in a vertical plane, the weight resting upon the wheel until the water has reached the lowest point where it is discharged.

Second. Impact wheels, driven by the force of spouting water that expends its percussive force against the floats tangentally to the course of rotation and at a right angle to the face of the floats or vanes.

Third. Reaction wheels, that are "enclosed," as it is termed, and filled with water under pressure, that is allowed to escape through tangental orifices, the force being derived from the unbalanced pressure within the wheel or from the reaction due to the weight of the water that is thrown off from the periphery.

Fourth. Pressure wheels, acting in every respect upon the principle of a rotary steam-engine, except in the differences that arise from operating with an elastic and a non-elastic fluid, the pressure of the

water resting continually against the floats or abutment, without chance to escape except by the rotation of the wheel.

To this classification might be added combination wheels, acting partly by the gravity and partly by the percussion force of the water; or acting partly by impact and partly by reaction, or by impact and pressure, which are common conditions of operation in water-wheels.

The water-wheel or water-power, as a mechanical subject, is apparently quite disconnected with shop manipulation, but serves as a good example for conveying general ideas of force and motion, and, on these grounds, will warrant a more extended notice than the seeming connection with the general subject would otherwise call for.

In the remarks upon steam-engines it was explained that power is derived from heat, and that the water and the engine were both to be regarded as agents through which power was applied, and, further, that all power is a product of heat.

There is, perhaps, no problem in the whole range of mechanics more interesting than to trace the application of this principle to water-wheels: one that is not only interesting but instructive, and may suggest to the mind of the apprentice a course of investigation that will apply to many other matters connected with power and mechanics.

The power derived from water by means of wheels is due to the gravity of the water in descending from a higher to a lower level; but the question arises, What has heat to do with this? if heat is the source of power, and power a product of heat, there must be a connection somewhere between heat and the descent of the water.

Water in descending from one level to another can give out no more power than was consumed in raising it to the higher level, and this power we will find to be heat.

Water is evaporated by heat of the sun, expanded until it is lighter than the atmosphere, rises through the air, and by condensation falls in the form of rain over the earth's surface, then drains into the ocean through streams and rivers, to again resume its round by evaporation, giving out power in its descent that we turn to useful account by means of water-wheels.

Evaporation is continually going on; the rainfall is likewise quite constant, so that streams are maintained within a sufficient regularity to be available for operating machinery.

The analogy between steam-power and water-power is, therefore,

quite complete. Water is, in both cases, the medium through which power is obtained; evaporation is also the leading principle in both cases, the main difference being that in the case of steam-power there is used a force arising directly from the expansion of water by heat, and in water-power a force which is an indirect result of expansion by heat.

Returning to the classification of water-wheels, gravity, or "overshot" wheels, as they are called, seem to be the most effective and capable of utilizing the whole effect due to the gravity of the water; but in practice this is not the case, and it is only under peculiar conditions that wheels of this class are preferable to turbine wheels, and in no case will they give out a greater per cent. of power than turbine wheels of the best class. The reasons for this will be apparent by examining the conditions of their operation.

A gravity wheel must have a diameter equal to the fall of water, or, to use the technical name, the height of the head. The speed at the periphery cannot well exceed sixteen feet per second without losing the effect due to the descending gravity of the water. This produces a very slow axial speed, and a train of multiplying gearing becomes necessary in order to reach the speed required in most operations where power is applied. This train of gearing, besides being liable to wear and accident, and costing usually a large amount as an investment, consumes a considerable share of the power by frictional resistance, especially when the gearing consists of tooth wheels.

Gravity wheels, from their large size and their necessarily exposed situation, are subject to be frozen up in cold climates; and, as the parts are liable to be first wet and then dry, or warm and cold by exposure to the air and the water alternately, the tendency to corrosion of iron, or decay if of wood, is much greater than in submerged wheels.

Gravity wheels, to realize the fullest effect from the water, require a diameter so great that they must drag in the water at the lower or delivering side, and are especially affected by back water, to which all wheels are more or less liable, from the reflux of tides or by freshets.

These are among the most notable of the disadvantages pertaining to gravity wheels, which have, with other reasons, such as the inconvenience of manufacturing them, first cost, and so on, driven such wheels out of use by the force of circumstances rather than by actual tests or theoretical deductions.

Impact wheels, or those driven by the percussive force of water,

including the class termed turbines, are now generally used for heads of all heights.

The theory of their action may be explained in the following propositions:

The spouting force of water is theoretically equal to its gravity.

The percussive force of water can be utilized to its full extent if its motion is altogether arrested by the floats of the wheel.

The force of the water is greatest by its striking against planes at right angles to its course.

Any force represented by the water rebounding from the floats parallel to their face, or at any angle reverse to the motion of the wheel, is lost.

This rebounding action becomes less as the columns of water projected upon the wheel are increased in number and diminished in size.

To meet the conditions of rotation in the wheel, and to facilitate the escape of the water without dragging, after it has expended its force upon the vanes, the reversed curves of the turbine arrangement become necessary.

Keeping these general principles in view, the apprentice will be able to understand in general the construction of impact wheels.

The modern turbine has been the subject of the most careful investigation, by able engineers, and there is no lack of mathematical data to be referred to and studied after the general principles are understood. It is a subject of great complicity, if followed to detail, and, perhaps, less useful to a mechanical engineer, who does not intend to confine his practice to water-wheels, than other subjects that may be studied with more advantage. The subject of water-wheels may be called an exhausted one, that can promise but little return for labor spent upon it with a view to improvements; the efforts of the ablest hydraulic engineers have not added much to the percentage of useful effect realized by turbine wheels during fifteen years past, and their present performance is quite equal to anything that can be hoped for in future.

This matter is alluded to for the reason that in choosing any particular branch for a specieal study, an apprentice should select such as are least perfect, and present the best chance for improvement, instead of such things as there is every reason to believe have reached a reasonable state of perfection, and are in the future to remain substantially the same.

The last statement of course applies only to a few branches in the engineering arts, and perhaps more fully to water-wheels than to any other.

Reaction wheels are used only to a limited extent, and will soon, no doubt, become extinct as a class of water-wheels.

In speaking of them, I will select what is known as Barker's mill for an example, because of the familiarity with which it is known, although its construction is greatly at variance with modern reaction wheels.

A query as to the principle of action in a Barker wheel, while it may be very clear in a scientific sense, still remains a puzzle to the minds of many who are well versed in mechanics, some contending that the power is directly from pressure, others that it is from the dynamical effect due to reaction. It is one of the problems so difficult to determine by ordinary standards, that it serves for endless debate between those who hold to different views; and, considering the advantage that is derived from such controversies, perhaps the most useful manner of disposing of the problem here is to state the two sides as clearly as possible, and leave the reader to determine for himself which he thinks right and which wrong.

Presuming the vertical shaft and the horizontal arms of a Barker wheel to be filled with water under a head of sixteen feet, there would be a pressure of about seven pounds upon each inch of surface within the cross arm, exerting an equal force in every direction. By opening an orifice at the sides of these arms equal to one inch of area, the pressure would at that point be relieved by the escape of the water, and the internal pressure be unbalanced to that extent. In other words, opposite this orifice, and on the other side of the arm, there would be a force of seven pounds that was not balanced, and would act as a propelling force in turning the wheel.

This is one theory of the principle upon which the Barker wheel acts, that has been laid down in Vogdes' Mensuration, and perhaps elsewhere, as an explanation.

The opposing theory is that, direct action and reaction being equal, ponderable matter discharged tangentally from the periphery of a wheel must create a reactive force equal to the direct force with which the weight is thrown off. To state it more plainly, the spouting water that issues from the arm of a Barker wheel must react in the opposite course in proportion to its weight.

The two propositions may be consistent with each other and even identical, but there still remains an apparent difference.

The latter seems a plausible theory, and perhaps a correct one; but there are two facts in connection with the operation of reaction water-wheels that seem to controvert the latter and favor the first theory, namely, that reaction wheels seldom utilize more than forty per cent. of useful effect from the water, and that their speed may *exceed the initial velocity of the water*. With this the subject is left as one for argument and investigation on the part of those who choose to consider it.

Pressure wheels, like gravity wheels, would, upon theoretical inference, be expected to give a high per cent. of power, the water resting with the whole of its weight against the vanes or abutments, and without chance of escape except by turning the wheel, would seem to meet the true conditions of realizing the whole force; and so it would, if such wheels had not to contend with certain mechanical difficulties that render them impractical in most cases.

A pressure wheel, like a steam-engine, must include running contact between water-tight surfaces, and, like a rotary steam-engine, running contact between water-tight joints that move at degrees of speed that varies in the same joint, and when it is considered that the most careful workmanship has never produced rotary engines that would surmount these difficulties in working steam, it can hardly be expected they may be overcome in using water, that is liable to be filled with grit and sediment, and lacks the peculiar lubricating property of steam.

A rotary steam-engine is in effect the same as a pressure water-wheel, and the apprentice in studying the first will fully understand the principles of both by supposing steam to be substituted by water.

Wind Power.

Wind power, aside from the objection of uncertainty and irregularity, is the cheapest source of power. Steam machinery, besides costing a large sum as an investment, is continually deteriorating in value, consumes fuel and requires skilled attention. Water-power also requires a large investment, greater in many cases than steam-power, and in most places the plant is in danger of destruction by freshets; but wind-power is cheap in every sense, except that it is unreliable for constancy except in special localities, and these, as it happens, are for the most part distant from other elements of manufacturing industry.

The operation of wind-wheels is so simple and so generally understood, that no reference to mechanism need be made here.

The force of the wind, moving in right lines, is easily applied to producing rotary motion, the difference from water-power being mainly in the weakness of the wind currents and the greater area of the surfaces required to act upon. Turbine wind-wheels have been constructed very much the same as turbine water-wheels.

In speaking of wind-power, the propositions about heat must not be forgotten; in fact the apprentice should so school his mind and habits of thinking that, whenever the subject of power is to be considered in any way, he will at once trace out the connection with heat.

We have seen how heat is almost directly utilized by the steam-engine, and how the effects of heat are utilized by water-wheels, and the same connection will be found with wind-wheels or wind-power; because currents of air are due to changes of temperature, and the connection between the heat that produces such air currents and their application as power is no more intricate than in the case of water-power.

Machinery for Transmitting and Distributing Power.

To construe the term, transmission of power, in a critical sense, it should, when applied to machinery, include nearly all that has motion; for, with the exception of the last movers, or where the power passes off and is expended upon the work to be performed, all machinery, of whatever kind, can be regarded as machinery of transmission. Custom has, however, confined the use of the term to such devices as are employed to convey power from one place to another, without including the organized machinery through which power is applied immediately to the performance of work.

Power is transmitted by means of shafts, belts, friction-wheels, gearing, and in some cases by water or air, as the conditions of the work may require. Sometimes such machinery is employed as the conditions do not require, because there is, perhaps, nothing of equal importance connected with mechanical engineering about which there exists so great a diversity of opinion or in which there is a greater diversity of practice than in devices for transmitting motion.

I do not refer to questions of mechanical construction, although the remark is equally true if applied in this sense, but to the kind of devices that are best in special cases.

It is not proposed, in this part at least, to treat of the construction of machinery for transmitting power, but to search after the conditions that should determine which of the several plans, whether belts, gearing or shafts, should be employed, and the principles upon which they operate.

Practical examples do not often furnish data as to the advantages of the different plans for transmitting power, because a given duty may be successfully performed by belts, gearing, or shafts, even by water, air or steam, and the comparative advantages of different systems is not always an easy matter to determine. Machinery of transmission being generally a part of the fixed plant, experiments cannot be made to institute comparisons, as in the case of machines; besides there are special or local considerations, such as noise, danger, freezing and distance to be taken into account, which prevent any rules of general application. Yet in every case it may be assumed that some particular plan is better than any other, and that plan can best be determined by studying first the principles of the mechanism, next the special conditions that exist, and thirdly precedents or examples.

A leading principle in machinery of transmission that more than any other furnishes data for strength and proportions is, that the stress upon the machinery, whatever it may be, is inversely as the speed at which it moves. For example, a belt two inches wide, moving one thousand feet a minute, will theoretically perform the same work that one ten inches wide will do, moving at a speed of one hundred feet a minute; or a shaft making two hundred revolutions a minute will transmit four times as much power as a shaft making but fifty revolutions in the same time, the torsional strain being the same in both cases.

This proposition argues the expediency of reducing the proportions of mill gearing and increasing its speed; but there exists other conditions that makes a limit in this direction, such as the speed at which bearing surfaces may run, centrifugal strain, jar, and vibration. The object is to fix upon a point between what high speed, light weight, cheapness of cost would suggest, and what the conditions of practical use and endurance demand.

(To be continued.)

REPORTS OF THE COMMITTEE ON THE MODE OF DETERMINING THE HORSE-POWER OF STEAM BOILERS.

At a Meeting of the Franklin Institute, held Nov. 19, 1873, it was resolved that the accompanying statement precede the reports, viz:

At the stated meeting of the Institute, held October 15th, 1873, the accompanying reports from the "Committee on the Mode of Determining the Horse-Power of Steam Boilers," were presented.

It was thereupon resolved that, while not formally adopting the views of either report, the Institute accept the same; and, further, that both reports be published in the Journal for the information of the members. The Chairman then gave a brief history of the work of the Committee, and concluded by urging its discharge.

It was, thereupon, on motion, resolved "that the Committee be discharged, and that the thanks of the Institute be presented to the gentlemen composing it for the faithful manner in which they had performed their laborious task."

It may be remembered that this Committee was constituted over three years ago with five members, and brought in a report on June 21st, 1871, and an additional report June 18th, 1872, both of which were published in the Journal.

At the meeting in October, 1872, the two reports were discussed, and the Institute referred the subject again to the Committee for more explicit directions, which would make the same available to practical engineers. A difference of opinion also existing as to the amount of evaporation which should be considered as horse-power, the Committee was enlarged by three additional members, representing the manufacture of modern sectional boilers, making the number of the Committee eight. The following reports, numbered 3 and 4, exhibit fully the two views taken of the question: ED.

REPORT NO. 3.

So far as the investigations of the committee have extended, they find no reason for changing the statement in relation to the practice of English boiler manufacturers of providing an evaporative capacity equal to one cubic foot of water at the boiling point turned into steam hourly under atmospheric pressure for each nominal horse power; this practice has grown up where forty pounds per square inch is regarded as high pressure.

The practice of American engineers makes a different demand on the boiler; higher pressures are required, and the boiler manufacturer has to furnish heat absorbing surface of greater strength; in fact, the chief requirements of the boiler to be used for a manufactory are strength and surface. These cost the maker money, and they are sought by the purchasers of boilers at the lowest price they can procure them. Under these conditions the practice of engine and boiler makers has for some years been growing away from the English precedents; the economy of higher steam pressure has been already sufficiently demonstrated to here require no further discussion, and the conclusions naturally resulting from these changes in practice seem irresistible; we therefore submit the facts.

It has been frequently suggested that the designation of the size or capacity of boilers by the term horse-powers, although it has been used for about fifty years, is inapt and uncertain—the term horse-power being a dynamic expression, and the dynamic effect of a given quantity of steam varying with the engine in which it is used.

To describe the size of a boiler in its evaporative capacity per hour, under stipulated conditions, is preferable.

The conditions vary with different boilers, and should entirely be in the control of the party assuming the responsibility of the performance of the boiler. They embrace temperature of feed, pressure of steam, quantity and form of fuel, arrangement of grate proportions, forms of furnace and flue, volume and force of draft, condition of heat-absorbing surface, and, in short, every thing that affects either the combustion of fuel or the absorption of heat by the boiler.

The making of any uniform empirical standard of evaporation, equivalent to a horse-power, applicable to all boilers that can be verified by experiment is impracticable, because changes in working pressure are attended with changes in the dynamic effect or power with the same evaporative capacity, and such changes are not in direct ratio either with the increased pressure or with the degree of expansion practised in the engine.

In presenting this matter to the notice of the Institute, it would seem proper to call attention to the phenomena resulting from varying steam pressure and variations in expansion.

To do this a series of diagrams have been prepared, copied and modified* from Professor Trowbridge's book on the subject—the

* The modification consists in making the atmospheric pressure the zero initial point in starting pressure, so as to correspond with the steam gauges now generally used, instead of an absolute vacuum 14·7 lbs. below the atmosphere.

result of extended experiments, made in the Novelty Iron Works, N. Y., and checked by careful comparison with other published experiments.

(No. 1.) The first diagram shows the number of pounds of water required to produce one indicated horse-power, in a non-condensing engine, at different pressures and different points of cut-off.

(No. 2). The second shows the theoretical quantity and the actual quantity of water required per horse-power per hour, with steam at 80 pounds per square inch pressure, cut-off at various points in the stroke. These experiments were made on engines of the slide-valve type, the valves at each end of the cylinder and clearances equal to five per cent. of the piston displacement.

The upper curve is obtained from an engine of more than ten cubic feet cylinder capacity, and the next lower curve from one of less than one cubic foot cylinder capacity.

The lowest line is from a computation of specific volume, according to Mariotte's Law," without clearances, and the line above it, from a similar calculation, embracing clearances equal to one-twentieth of the piston displacement.

(No. 3.) The third diagram shows the increase of horse-power due to increased pressure with the same rate of evaporation.

(No. 4.) The fourth diagram shows the quantity of water required to be evaporated in a boiler to produce one horse-power with different steam pressures in a theoretically perfect non-condensing steam engine.

An examination of these diagrams will serve to show the impracticability of establishing any uniform system of rating steam boilers in horse-powers by any easy mode of computation.

It is the experience of all engineers that moderate excess of steam boiler capacity, beyond the actual requirements of the engine, is attended with economy in fuel, and a stint of boiler with waste of fuel.

In view of variations of capacity of the same boiler under varied conditions, the discontinuance of the term horse-power, as descriptive of the size and capacity of the boiler, would appear to be proper; and it is suggested as preferable that purchasers and makers should, instead, describe fully and in accurate terms the evaporative capacity of boilers proposed, and the conditions under which they are to be worked and tested, or to specify the indicated horse-power to be developed in an engine under fully and exactly stipulated conditions of speed, pressure, economy and grade of expansion.

In conclusion, the following mode of making tests of the evaporative capacity of steam boilers is suggested as being easily managed by persons practically familiar with steam machinery, and only involving apparatus which can be readily procured in most manufacturing establishments.

That the water be weighed in, and pumped from, a tank placed on a platform scale, the temperature at which it enters the boiler measured by a thermometer inserted in the feed pipe, the pressure at which the steam is delivered is determined by a steam gauge, and its temperature by a thermometer inserted in the steam pipe near the boiler.

In case of boilers exceeding 100 cubic feet hourly evaporative capacity, measuring of the water in a tank is preferable as being more convenient.

A convenient means of applying thermometers in water and steam pipes is to screw a hollow plug of iron, open at the top and closed at the bottom, vertically into the upper side of the pipe, so that the lower portion of the plug is in the current flowing through the pipe. Into the cavity of the plug a little quicksilver is dropped, and the bulb of the thermometer is inserted in it. The function of the quicksilver is to secure prompt conduction of heat from the tube to the thermometer bulb.

The preferable form of thermometer for this use is that known in the trade as chemical thermometers; the whole instrument, including its porcelain scale, being enclosed in a glass tube.

The advantage of this mode of applying thermometers is that the thermometer is not exposed to pressure, as it is when directly inserted in the pipe, and, in the event of breaking, no leak from the pipe ensues, and the plugs, which are inexpensive, remaining in the pipe, the thermometer can be readily applied or removed without interruption to the working of the boiler.

The weight of a cubic foot of water at 212° is almost exactly 60 pounds avoirdupois.

When the water is measured at temperatures say between 45° and 70° Fahrenheit, 4¼ per centum should be added for the increase in volume, from expansion in heating to 212°.

The temperature of steam when not superheated is most easily deduced from the pressure, as shown in a table, marked No. 5, from Rankine; if superheated, a thermometer inserted in the pipe is a convenient mode of ascertaining it; for converting feed water of

other temperatures than 212° to an equivalent quantity of that temperature, and for converting steam of other pressures than that of the atmosphere to an equivalent quantity at atmospheric pressure, the annexed table, also from Rankine, marked No. 6, serves to conveniently make the conversion.

As the committee do not recommend the testing of all boilers at one uniform pressure, conversions such as are accomplished by these tables are useful in making comparisons of results from boilers tested under different conditions of feed temperature and steam pressure.

The committee are of the opinion that it is not properly within the province of a scientific association to attempt to adjust commercial standards, nor to engage in the interpretation of contracts between buyer and seller, and have endeavored to show what has been the practice of different parties in making boilers and engines, and what are the requirements in evaporative capacity for producing one horse-power under different conditions, and, in conclusion, respectfully suggest that controversies in such questions are most easily avoided by employing competent engineering skill in selecting and purchasing boilers.

The number of elements that necessarily enter into the successful operation of boilers is so great, that it is unreasonable to look for adequate skill among those not specially educated and practically familiar with the subject.

The computations required to convert different temperatures of feed to an equivalent in a fixed standard temperature, and to convert varying temperatures and pressures of steam into an equivalent in a fixed standard, are not such as persons engaged in mercantile and manufacturing pursuits are conversant with; and whilst there is no mystery surrounding these operations, there are wide differences of opinion between engineers as to the proper basis of calculations for converting thermal units into foot pounds or other dynamic expressions.

This wide difference of view between careful and intelligent experimenters is sufficient to place others on their guard in making calculations of such conversions, and forms a strong argument in favor of stipulating fully and exactly the conditions under which steam boilers are to be operated, and then testing them under such conditions.

W. Barnet Le Van, William H. Wahl,
S. Lloyd Wiegand, Thos. L. Luders.

Report No. 4.

The undersigned members of the Committee on the Horse-power of Steam Boilers, disagreeing with the views expressed in the report presented, ask leave to submit the following report.

After reconsideration of the subject referred to the original committee, no good reason appears for modifying the preliminary or final report of said original committee, in the definite conclusion that the horse-power of boilers for stationary engines and for heating purposes is properly defined as the *capability to evaporate a cubic foot of water per hour from and at the temperature of* 212° *Fah.* This, as stated in our previous report, should be effected with a fair average economy of fuel.

The Committee are confident that three-fourths of all stationary boilers are made and sold upon the basis of "horse-power," although many if not most of them are further qualified by some specification of dimensions which govern and control the *nominal* horse-power of the makers and the purchasers.

Upon inquiry, it seems there is generally attached to the number of horse-power at which boilers are rated, somewhat of the value given to arbitrary numbers in numbering machines of different sizes; but yet *by tradition* some length, diameter, number of flues or of tubes, with sizes of same, size of fire-box, or other particular dimensions, correspond to certain numbers of horse-power in the minds of the makers. In reply to the question as to "what constitutes the horse-power," the general response is referred to the heating surface, which is taken out in very different values for different kinds of boilers, and with sometimes other additions or deductions for supposed efficiency of surface.

Makers have generally an ideal or assumed grate surface, flue area, chimney or other condition appertaining to any of their boilers of a given size, but it does not seem that any definite rules are admitted. With this uncertainty of positive laws of proportion, boilers of any nominal horse-power of any fixed type are supplied by old and known boiler makers, of much the same weight, proportion and capacity. If cross-questioned too closely as to the surface, cubic contents, weights, exposures, *the practical boiler maker* contents himself with the assertion that such and such a boiler is 20, 30 or 50-horse-power, either for buyer or seller.

The relations of buyer and seller in the purchase and sale of a

boiler are the offer of so much money by one to pay for material or work by the other, both understanding that the boiler should have certain capability, which is rated as "horse-power."

Nor do the Committee find any reason to modify the nominal value of the horse-power of steam boilers to be based on any supposed improvement of engine, use of higher steam or discoveries of absolute dynamic force of evaporation of water (or heat used in evaporating water).

The average *stationary engine* of America and of to-day does not probably produce a horse-power in impulse of machinery or raising of water, with so little fuel as the average engine of Watt's time.

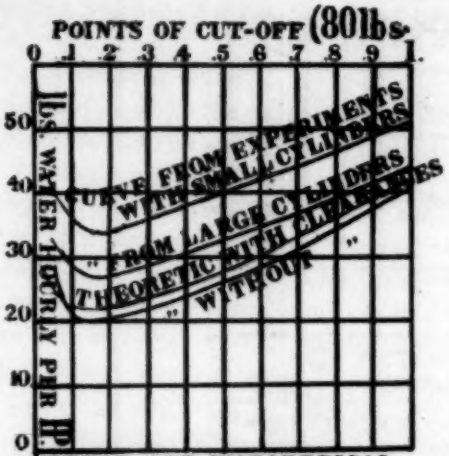
Cheapness of original construction and direction of service without cost of repair, are more studied, as a rule, than economic effect.

High-pressure non-expansion slide-valve engines predominate greatly, and they are far below, in economy of fuel, the condensing engine, worked expansively with double-beat valves, in use in England, where the value of a "horse-power" of the boiler was estab lished.

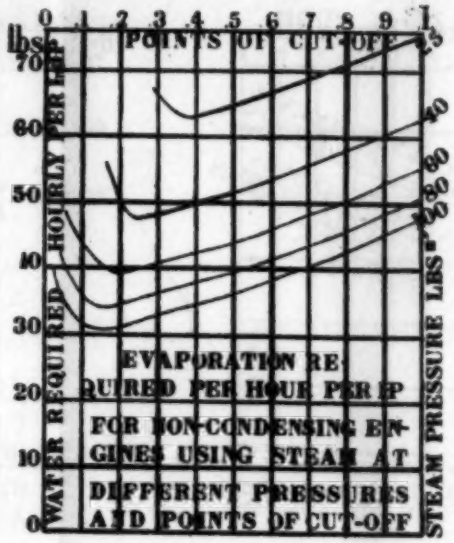
The thermo-dynamic effect of the evaporation of a cubic foot of water from and at 212° is about 23-horse-power, but no practical result coming near that figure has been considered possible.

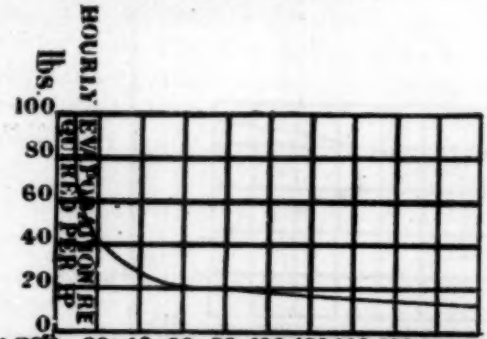
There can be quoted instances where the *effective or actual* horse-power is produced with the combustion of 2 lbs. of coal per hour, and the Committee can quote one instance in the United States of such performance by 2·13 lbs. of coal (under 2 lbs. of fuel *burned*). This instance is equivalent, with a fair boiler, to the evaporation of less than one-fourth of a cubic foot of water for an *actual* horse-power. Such examples are too infrequent to disturb the general rule. Besides, the purchaser of a boiler by a rating of horse-power expects to receive the boiler that custom has established, and that any special advantage derived from construction of engine or economical use of steam will inure to him. Suppose improvement of engine to reach one-half the theoretical limit, the absurdity of the proposition that a boiler maker could supply the owner of such an engine on a contract for a 50-horse-power boiler, with a 5-horse-power one, is too manifest for discussion.

To the further requirements of the Institute, that your Committee shall report directions for ascertaining the quantity of feed-water and its temperature, and the temperature of the steam generated, and the method or figures necessary to reduce the result to equivalent values with feed-water and steam assumed to have been at 212°, so that the

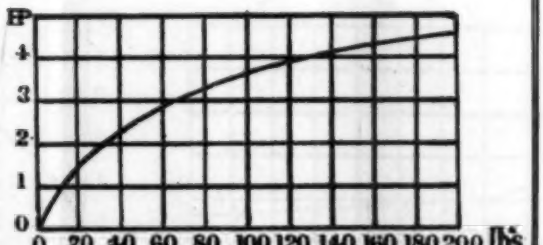


ACTUAL AND THEORETICAL EVAPORATION AT 80 lbs. PER SQ." REQUIRED PER HP FOR NON-CONDENSING STEAM ENGINES





VARIATIONS IN W'TS. OF WATER PER HP REQUIRED FOR NON-CONDENSING ENGINE USING STEAM OF DIFFERENT PRESSURES



VARIATIONS IN HP OF NON-CONDENSING ENGINES USING EQUAL W'TS. OF WATER IN STEAM OF DIFFERENT PRESSURES.

NO. 6.

LBS.	TEMPERATURE OF FEED WATER FAH.											
	32	50	68	86	104	122	140	158	176	194	212	
212	115	117	115	113	111	110	108	106	104	102	100	
230	120	118	116	114	112	110	108	106	104	102	101	
248	120	118	116	114	113	111	109	107	105	103	101	
266	121	119	117	115	113	111	109	107	106	104	102	
284	121	120	118	116	114	112	110	108	106	104	102	
302	122	120	118	116	114	112	111	109	107	105	103	
320	122	121	119	117	115	113	111	109	107	105	103	
338	123	121	119	117	115	114	112	110	108	106	104	
356	123	122	120	118	116	114	112	110	108	106	104	
374	124	122	120	118	117	115	113	111	109	107	105	
392	124	123	121	119	117	115	113	111	109	107	106	
410	125	123	122	120	118	116	114	112	110	108	106	
428	125	124	122	120	118	116	114	112	111	109	107	

NO. 5.

TEMPERATURES IN FAHRENHEIT DEGREES.

0	212
5	227
10	240
15	250
20	259
25	267
30	274
35	280
40	287
45	292
50	298
55	303
60	308
65	312
70	316
75	320
80	324
85	328
90	331
95	334
100	337

LBS. PRESSURE PER SQ. INCH ABOVE ATMOSPHERE.

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number of horse-power of a boiler can be readily ascertained in accordance with the rule by *practical engineers*, your Committee answers:

1st. The quantity of water.

Having ascertained by the gauge cocks or the glass gauge the level of water at the time of commencing the trial, and having the same level at the moment of completion, the water used can be measured by a meter or in a tank (the capacity of which may be easily computed); or, in the absence of either of these, the supply of the boiler may be taken from any vessel by a temporary connection, which vessel shall be supplied with water from time to time, *weighed in*.

A cubic foot of water at 212° weighs almost exactly 60 lbs. If the temperature of the feed-water is between 45° and 70° (limits rarely exceeded), there is to be added 4¼ per cent. to the measured quantity of water (when it is measured, not weighed) for expansion between the temperature of feed and 212°.

2d. The temperature of feed water and of steam.

The temperature of feed-water can be taken by an ordinary thermometer. That of steam is practicably that of the boiler at any point not far removed from the surface of the water, and can be ascertained by inserting at such a point a well or little open cell of wrought or cast iron filled with mercury, in which mercury bath the bulb of a high temperature thermometer can be inserted. The loss of heat in conduction from the steam to the bulb is insignificant, and the thermometer will indicate, within a fraction of a degree, the proper temperature of the steam.

But the more ready way is to take the temperature as a deduction from the pressure gauge. (Of course it is necessary to have a verified pressure gauge on the boiler in such a case).

The following table gives the temperature corresponding to pressure from that of the atmosphere to 100 lbs. above, varying 5 lbs. The intermediate temperature can be taken out by interpolation:

(After Rankine).

Atmosphere,	5	10	15	20	25	30	35	40	45	50	lbs.
	227	240	250	259	267	274	280	287	292	297	Fah.
	55	60	65	70	75	80	85	90	95	100	lbs.
	303	308	312	316	320	324	328	331	334	337	Fah.

3d. The factor for evaporation, &c.

Having the quantity of water, the temperature of the feed-water and that of the steam, the following table from Rankine gives the multiplier to be used in the several cases:

Boiling Point, Fah.	Initial Temperature of Feed-water.										
	32°	50°	86°	86°	104	122	140	158	176	194	212
212	119	117	115	113	111	110	108	106	104	102	100
230	120	118	116	114	112	110	108	106	104	102	101
248	120	118	116	114	113	111	109	107	105	103	101
266	121	119	117	115	113	111	109	107	106	104	102
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392	124	123	121	119	117	115	113	111	109	107	106
410	125	123	122	120	118	116	114	112	110	108	106
428	125	124	122	120	118	116	114	112	110	109	107

4th. The steam issuing from the boiler should be dry steam.

No rule can be given to judge of this; but the practical engineer, in testing a boiler, will institute such means as he finds readiest to satisfy himself on this point.

The allowance for wet steam and for loss of efficiency of the boiler in this way (and apparent excess of evaporating from this cause) is purely a matter of judgment.

To ascertain the evaporative capacity of the boiler, the trial should be made under the usual conditions of draft and pressure of steam, also of a good quality of coal (anthracite or bituminous), for which the boiler is designed.

The boiler being put up to its working pressure, the fire should be clean, and at an average level at the time of starting, and be at the same level and condition at the conclusion. The ashes and clinkers in the ash-pit must be deducted from the coal used.

Another and more certain plan is to have the boiler up to its working pressure, draw the fire, and fire up with enough wood to kindle and fresh coal both weighed in, and at the conclusion draw the fire, and

weigh refuse ashes, clinkers and coal, for deduction. In this case, the evaporative capacity of the boiler should be estimated from the time the fire is bright, but for the economy, the total water evaporated from the commencement is to be divided by the total weight of combustible used minus the refuse.

The trial, if accuracy is desired, should not be less than of ten hours' duration. A longer trial would reduce the uncertainties to a smaller proportion.

EDWD. BROWN,
JOHN H. COOPER,
ROBT. BRIGGS.

Philadelphia, Oct. 15, 1873.

ON A NEW HYDRAULIC RAILROAD CAR BRAKE.

By WILLIAM M. HENDERSON, Philadelphia.

A paper read before the Franklin Institute Oct. 15, 1873.

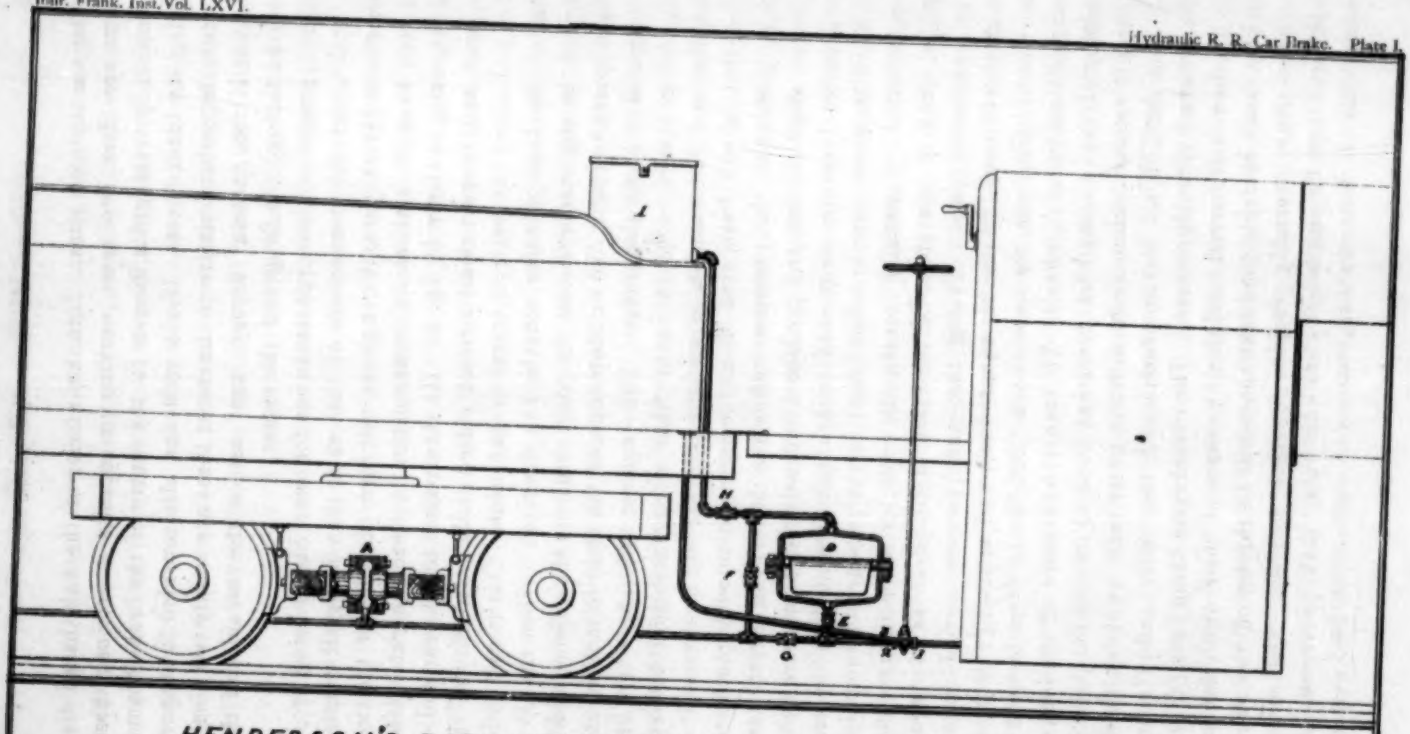
The principle involved in the operation of this brake is that of hydraulic pressure, and the motive power is derived directly from the steam-boiler of the locomotive, and under the control of the engineer.

There is first a three-branch or two-way cock placed underneath the foot-plate of the engine, its plug actuated by a stem carried up through the foot-plate, and furnished with a horizontal lever at top, carrying an index pointer, traversing a quadrant plate marked *on* and *off*, with gradation marks between, as a guide to the engineer in operating the brakes; and there is also a small pressure gauge, placed conveniently before him, to show him the pressure he is applying. The nozzle of the cock, marked 1, is connected by a short piece of wrought iron pipe directly to the water space of the boiler; the opposite nozzle, marked 2, is connected by wrought iron pipe and flexible hose connections, furnished with valvular couplings between the cars, as usual in such cases, and leads directly to pressure boxes placed between the brake beams of each truck; the third nozzle, marked 3, is connected directly to the water tank supplying the boiler with water.

The construction of the pressure boxes is as follows: A cylindrical vessel of cast iron is furnished, having flanges at either end; it is about 9 inches in diameter and 3 inches deep, the inner diameter being about 5 inches. Two flexible dish-shaped diaphragms are next introduced, back to back, having about half an inch space between them, and are secured in position by rings bolted firmly to the drum,

making an air-tight joint. Into the interior of the dish-shaped diaphragm are fitted two rams, working in opposite directions; these are bolted by rectangular flanges to the centre of the brake beams, carrying the brake shoes. Guide rods are also provided to support the drum in position relative to the rams; these are simply two pieces of ⅞ round iron, passing through lugs cast on the two sides of the drum and through the flanges of the rams.

The operation of this apparatus is as follows: Steam being up in the boiler, and the connections of the main pipe being all coupled between the several cars, the engineer will turn the plug of the two-way cock so as to establish a communication between the water tank and the main, as shown by fig. 4. He then passes to the rear end of the train, and opens a small air-cock placed at the extremity of the main, and allows the water to travel to that point. This it will do by virtue of the head of water contained in the tank. When the air is expelled the engineer will close the cock, return to the engine, and is then prepared to start. We will now suppose the train in motion, and it is desired to apply the brakes. The engineer will simply turn the plug of the two-way cock so as to make a communication between the boiler and the main, as shown by fig. 5. It will be observed, in doing this, he will have shut off all communication with the water tank. Now, then, the pressure within the boiler will exert itself upon the water column, and produce a hydro-dynamic pressure equal to the boiler pressure upon each square inch presented by the area of the rams, when turned on full head; or the pressure to be applied can be varied by partially opening the cock; or a special provision can be made in the shape of the valve openings, so as to produce such graduated result. Taking the usual pressure carried on our locomotive boilers, 120 lbs. per square inch, and applying this pressure to our 5-inch rams, we have above 2800 lbs. of force brought to bear upon each pair of wheels. To take the pressure off the brakes, the plug of the two-way cock is turned back to its original position, opening a communication again with the water tank, as shown by fig. 4. This shuts off all communication with the boiler, and of course destroys the hydraulic pressure. The diaphragms being thus relieved will recover their normal condition by reason of their own elasticity, and the beams carrying the brake shoes will be thrown off the wheels by the springs invariably provided for that purpose. The surplus water will then be discharged into the water tank, preventing any waste either of water or heat, becoming a part of the feed-water to



HENDERSON'S PATENT, HYDRAULIC RAILROAD CAR-BRAKE.

PHOTO-LITH. BY A. DICKES, 125 SOUTH FOURTH ST. PHILA.

HENDERSON, DEL.

be returned to the boiler. There are stops obviously arranged between the body of the two-way cock and its plug, in such manner that the plug can never be turned so as to open a communication between the steam-boiler and the water tank. In order that the force of applying the brakes shall not be of an objectionable concussive or jarring nature, two means have been provided: *first*, an air-vessel placed on top of the pressure boxes, which will furnish a cushion of air to absorb it; and, *second*, springs of rubber or other elastic material placed between the brake beams and the shoes to relieve it.

The above-described apparatus is all that will be required to efficiently equip a train of cars south of Mason and Dixon's line, and will be equally efficacious for about nine months in the year in the Northern States. To adapt this invention for low temperatures, the following device is made attachable:

A cast iron cylindrical vessel is provided, of a capacity to contain sufficient non-freezing fluid to charge the maximum number of pressure boxes usually employed on a train of cars. It is made in halves, and embraces at the joint, where it is bolted together, the flange of a double corrugated flexible diaphragm, making an air-tight joint. The fluid to be used for operating the brake pressure boxes is placed above the diaphragm, and the pressure from the boiler is applied below. As the pressure on either side will be the same during its operation, the medium is therefore a mere separator, preventing the fluids on either side of it from commingling. For the non-freezing fluid, glycerin and water in equal parts is preferred, which is safe to about 30° below zero. (Glycerin itself never freezes). The glycerin chamber is connected to the main by a short tubular connection, furnished with a stop-cock, E. Leading away from the other end of this chamber is another tube connection, making an advanced connection with the main, and is also furnished with a stop-cock, F. Between the point of junction of these two connections there is placed another stop-cock, G. When the cocks E and F are shut and G opened, the brakes will be operated entirely by water from the tender tank. When the cocks E and F are opened and G is shut, whatever fluid is used to operate the brakes must come solely from the glycerin chamber. The pressure from the boiler, acting upon the underneath side of the diaphragm, will cause a discharge of the fluid to operate the diaphragm of the pressure boxes, as before; and when the brakes are let off this fluid will return to the glycerin chamber, the diaphragm making room for it by adjusting itself to its normal state, and the water under

pressure will be delivered into the tender tank precisely as previously described. In order that the glycerin chamber shall remain at all times fully charged with fluid, a tank or reservoir is provided on the tender, containing an excess quantity. The pipe proceeding from this tank to the glycerin chamber has a check-valve fitted to it, opening towards the glycerin chamber, so that this result must be fully accomplished; for, if a vacuity should occur in the glycerin chamber from loss by accidental leakage, the loss will be immediately made good from the reservoir, while a disposition for any of the fluid to return is instantly checked by the closing of the check-valve.

This brake can be applied equally well to the outside of the wheels, and is adapted to any kind of truck, either four or six-wheeled.

As compared to other brakes, the saving effected consists in doing away with the steam-pump and receiver, all cylinders, pistons, stuffing-boxes, lever-rods and springs, all packing, lubricating, and a total exclusion of dust.

BELTING FACTS AND FIGURES.

By J. H. Cooper.

(Continued from page 329.)

The following notes on belting are taken from Mr. B. F. Sturtevant's illustrated catalogue of Pressure Blowers, Boston, Mass.:

"Double Belts are calculated to be one-third of an inch thick, single belts one-fifth of an inch thick. The holding power of the belt is governed wholly by its tension or tightness and the condition of its surface, the diameter of the pulleys having nothing to do with it, and is capable of being increased by tightening to 350 pounds to 1 square inch of cross section.

"As a general rule, belts running from a large to a small pulley, slip on the large and not on the small one, as is commonly supposed. This is explained as follows: The pressure per square inch with which the belt hugs the small pulley is just as much greater as the small pulley is less in diameter than the large one, and the friction of the belt more than follows the increased pressure. For example: If you cover the small pulley on the counter with leather, to prevent slipping, you must also cover the driving pulley on the main line, or you get no benefit from covering the small pulley. These remarks apply to horizontal belts.

"A table is given for finding the width in inches of double main

belts for driving his patent pressure blowers, which is based on the statement that a belt, one inch wide, having a velocity of 1000 feet per minute, will give one horse-power. This is also equivalent to a surface velocity of 83⅓ square feet of belt per minute per horse-power, and a working strain of 33 pounds per inch width of double belt, or 99 pounds per square inch of cross section of leather.

"New belting, such as is generally used for the driving belts, on polished iron pulleys, will only transmit from one-third to one-fifth the power, without slipping, that the same belt will after it has been in use from one to two months.

"The belts for driving the blowers are not exposed to the wear and tear of shippers as lathe belts are; all of them run over small pulleys in proportion to the width of the belts. Hence I have recommended a scale of thicknesses of belts in proportion to the widths; the lighter the belt the tighter it hugs the pulley, for the reason that all unnecessary weight of leather tends to lift itself off the pulley when going around it at a great velocity, and some of these belts travel at a velocity of 5000 feet per minute.

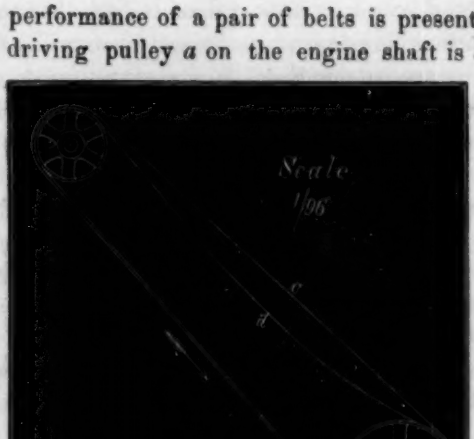
"Belting, as it is generally manufactured, as an article of merchandise, is intended for all purposes for which belting is used; but when parties are desirous of having everything about the blower just as it should be, they will see that their belts are made exactly to suit their work.

No. of fan.	Diam. of pulley.	Face of pulley.	Breadth of belt.	Thickness of belt.	Revs. of fan per min.	Diam. driving pulley.	H. P. required.
00	1⅞	1½	1¼	·08		21	
0	2¼	1¾	1½	·09		21	
1	2⅝	2	1¾	·11	4135	21	·5
2	3	2⅜	2	·12	3756	24	1
3	3½	2¾	2⅜	·13	3250	28	1·8
4	4¼	3¼	2¾	·15	3100	32	3
5	4⅞	3⅞	3¼	·16	2900	36	5·5
6	5¾	4½	3⅞	·18	2820	42	9·7
7	6⅞	5⅛	4½	·20	2600	48	16
8	7⅞	6	5¼	·22	2270	54	22
9	9⅛	6⅞	6	·24	2100	48	35
10	10¼	8	7	·25	1815	54	48

"In the above table all the dimensions are in inches. To give some idea of the proper length of belt, the centre of the driving pul-

ley is placed 3½ times its diameter from the centre of the fan, and two and one-seventh times above it. The driven pulley on the driving pulley shaft is 18 inches diameter, and that in turn is driven by a 54-inch diameter pulley and belt of double thickness. The centres of the 54-inch and 18-inch pulleys are placed about three times the diameter of the larger pulley apart, and nearly at same height from floor.

"A curious performance of a pair of belts is presented in the following: The driving pulley *a* on the engine shaft is 5 ft. diameter



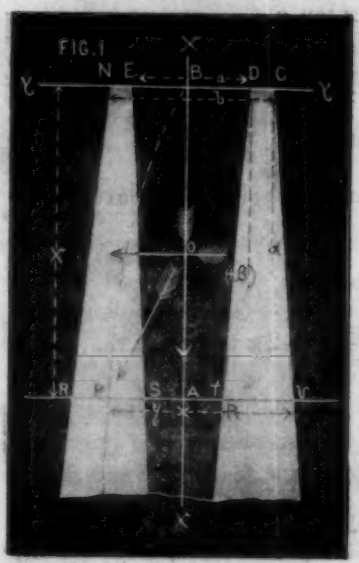
and runs 75 revolutions per minute; the driven pulley *b* on the line shaft is 3 ft. diameter and about twenty feet distant in a line near 45° with the horizontal; both pulleys are wooden drums covered with leather, and have sufficient breadth of face for two 12-inch belts. When this arrangement was started two 12-inch single leather belts were put on side by side, and for some time were run in that way, but never satisfactorily. After many fruitless efforts to obtain a uniform action of the two belts, one accidentally mounted the other, the two running thenceforth as one double belt; in this way they drove the line shaft better than ever before. Many experiments were tried in the relative tightness of the two belts, which invariably proved that the best driving was always secured when the inside belt *d* was very slack, sagging say 12 to 18 inches, and the outside belt *c* quite tight; the working sides, of course, running close to each other, as shown in the cut. This was in use some 30 years ago in a factory near this city."—J. S. Lever, Philada.

THE STABILITY OF TOWERS AND CHIMNEYS.

By C. A. Evans, Civil Engineer.

This subject has not been treated in the standard works on construction with the detail of which it is susceptible. Many points relating to it are here, the writer thinks, presented for the first time, and especially that portion referring to circular sections.

The stability of vertical shafts of masonry is tested by the pressure of the wind during hurricanes. As usually constructed, these shafts have a batter on the outside and are carried up on the inside, particularly in the case of chimneys, in a series of steps. The latter measure but a few inches in width, and should be so arranged that a batter line may pass through their reëntrant angles. Hence the more numerous the steps, the nearer will they approach in effect to a regular batter. Such a batter, though desirable, yet is not introduced with the view to save workmanship. A chimney, consequently, is divided by the steps into a series of divisions, the thickness of each of which is constant when brick is the material employed. In the following investigation we will consider the steps to be replaced by the batter line passing through their reëntrant angles, and the small amount of material lying outside of this line will, therefore, not be regarded. Its influence, which is at most but very small, is to increase the stability slightly above what will be determined.



In plan, masonry shafts are generally square or round. Octagonal and kindred sections, though given sometimes to chimneys and towers, yet approach so nearly practically to circular sections, that these may be substituted for them.

In what follows we will let, Fig. 1:—

$x = \overline{BA}$ = height of any portion measured from the top.

$y = \overline{AP}$ = distance from the axis at which the line of resistance cuts the lower section.

$a = \overline{E\,D}$ = diameter or side of the opening at top.

$b = \overline{N\,C}$ = external diameter or side of the chimney at top.

p = pressure of the wind per sq.ft. on a flat surface.

u = weight of material per cu. ft. R = radius of any section in the circular chimney.

α and β = outside and inside batter respectively.

In the figure $+\beta$ is shown, and $-\beta$ would be shown by the batter lying on the other side of the vertical, thus making it analagous to the outside batter; which position it usually occupies in large chimneys. The condition $\beta = o$ makes the inside of the shaft vertical; its usual direction in light-houses. We will consider first the shaft with a

Square Section.

For the solidity of any portion of the chimney or tower we have from the fig.:—

$$\overline{NCVR} - \overline{EDST} = \frac{(b + 2x\tan\alpha)^3 - b^3}{6\tan\alpha} - \frac{a^3 - (a - 2x\tan\beta)^3}{6\tan\beta}$$

For the distance of the centre of gravity of any section $\overline{N\,C\,V\,R}$ from $\overline{R\,V}$ or its base, we deduce:—

$$\overline{A\,O} = \frac{x(3b + 2x\tan\alpha)}{6(b + x\tan\alpha)}$$

And for the pressure upon this section:—

$$p\,x\,(b + x\tan\alpha)$$

Finally, by taking the moments around the point P, we have for the equation of the line of resistance:—

$$y = \frac{\frac{p}{u}\,x^2\,(3b + 2x\tan\alpha)}{\frac{(b + 2x\tan\alpha)^3 - b^3}{\tan\alpha} - \frac{a^3 - (a - 2x\tan\beta)^3}{\tan\beta}} \qquad (1)$$

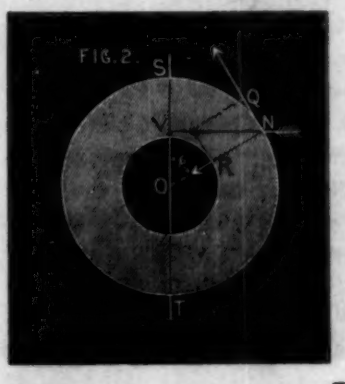
We will pass now to the

Circular Section.

The expression for the solidity of any portion is in this case:—

$$\overline{NCVR} - \overline{EDST} = \frac{\pi(b + 2x\tan\alpha)^3 - \pi b^3}{24\tan\alpha} - \frac{\pi a^3 - \pi(a - 2x\tan\beta)^3}{24\tan\beta}$$

To obtain an expression for the pressure on the surface of the shaft exposed to the wind, we have for the pressure at any point N of it, Fig. 2:—



$$p\ \mathrm{R}\ d\ \varphi\ \sin\ \varphi,$$

and this is in the direction $\overline{\mathrm{N\,V}}$. Resolving this pressure into two others, one tangential and the other normal to the surface at N, we have for the latter or effective pressure:—

$$p\ \mathrm{R}\ \sin^{2}\varphi\ d\ \varphi,—$$

and, therefore, we may write for the total pressure on $\overline{\mathrm{S\,N\,T}}$,

$$p \int_{\circ}^{\pi} \mathrm{R}\ \sin^{2}\varphi\ d\ \varphi,—$$

which, by multiplying by $d\ x$ and substituting the value of

$$\mathrm{R} = \frac{b}{2} + x\ \tan\ a,$$

becomes the pressure on the entire portion x of the chimney:—

$$p \int_{\circ}^{x} \left(\frac{b}{2} + x\ \tan\ a\right)\ d\ x \int_{\circ}^{\pi} \sin^{2}\varphi\ d\ \varphi$$

The second integral being equal to $\frac{1}{2}\ (\varphi—\cos\ \varphi\ \sin\ \varphi)$, we have by taking it between the limits indicated and completing the integration of the expression,—

$$\frac{\pi\ p\ x}{4}(b + x\ \tan\ a)$$

On examining this expression, we perceive that it equals a pressure of $\frac{\pi\ p}{4}$ uniformly distributed over the sectional area $\overline{\mathrm{N\,C\,V\,R}}$. Hence the centre of this pressure is at O, as in the case of the square chimney. Or, by multiplying the preceding integral by x and integrating, we obtain the moment of the total pressure around the axis of y. This, divided by the pressure, will give the lever arm $\overline{\mathrm{B\,O}}$: from which the length of $\overline{\mathrm{O\,A}}$, as previously found, may be deduced. Consequently, we obtain for the equation of the line of resistance by taking the moments around P:—

$$y = \frac{\frac{p}{u} x^2 (3b + 2x \tan \alpha)}{\frac{(b + 2x \tan \alpha)^3 - b^3}{\tan \alpha.} - \frac{a^3 - (a - 2x \tan \beta)^3}{\tan \beta.}}, \quad -$$

Which is identical with eq. (1), in the case of the square chimney. We therefore conclude that *the lines of resistance in a square and in an equally high circular shaft are identical in shape and position, provided the diameters of the one are equal to the sides of the other.* This is accounted for by the peculiarity of the round tower, though containing less material, being subject also to a lesser pressure. As far as regards the amount of material, and under similar conditions, a circular section is preferable to a square section.

The value of y may be written for either section, in terms of the diameter or side of it:

$$y = q (b + 2x \tan \alpha). \qquad (2)$$

In which q represents a fraction, or coefficient of stability, that locates the line of resistance, and consequently determines the stability of the shaft. At the *lowest section, or base* of the shaft we may assume $q = \frac{1}{3}$ for square, and $q = \frac{1}{4}$ for round shafts. In the round shaft it is well to keep the line of resistance a little further in than in the square one; for the outer edge in the former is not as extensive and strong as in the latter. Nevertheless, the foregoing values of q for the base admit of a fluctuation, but of not more than *six hundredths* one way or the other. In the one case we would increase the stability of the shaft beyond necessity, and in the other case we would diminish it too much. The values of q as given may be considered as mean values, and should, therefore, be used in constructing new works. In determining the stability of shafts already built, however, if their values of q at the base lie within the limits indicated, they may be regarded as well constructed. If these values pass one limit they may be considered as unnecessarily heavy, and if they pass the other limit, they should be strengthened.

Having equated eqs. (1) and (2), substituted for x the entire height of the chimney, and assumed the proper value of q, the value of b, tan α or tan β, may be deduced from the resulting equation according to the rest of the quantities assumed. After this unknown is determined, it remains to ascertain the position of the line of resistance. For this purpose values of x are assumed, commencing with 0, or at

the axis of y, and increasing gradually by 20, 30, 40 or 50 ft., according to the height of the shaft; and then deducing the corresponding values of y. In order to plot the line, a drawing of the shaft should be made in which the horizontal scale is exaggerated five or ten times. The advantages of such an exaggeration are, that we obtain a small drawing, easily handled; that the curvature of the line is intensified, thus making it more perceptible, and that the horizontal distances can be accurately measured in locating the section of least stability. The portions of the line of resistance included between the joints determined, may be sketched in with ease and correctness. The joint of least stability is indicated, not by where the line approaches nearest to the outside of the shaft, but by where this approach is nearest in proportion to the distance to the axis of the tower from the line. This ratio of the inner to the outer segment of the half section containing the line of resistance, is ∞ at the top, diminishes very rapidly as we descend, becomes a *minimum* at the section of least stability, and finally when $q = \frac{1}{4}$ or $\frac{1}{3}$ increases at the base to 1 or $\frac{1}{2}$. The value of ∞ at the top shows that the shaft there can never be overthrown. Evidently this is the case, for the line of resistance coincides there with the axis of the shaft. Such a ratio as the foregoing may be regarded as a coefficient of stability, which it really is. The stability of all the sections may also be determined in the same manner as that of the lowest section, that is, by deducing the values of q for them. But this process is much more laborious than the one we have described. The joint of least stability, indicated by the maximum value of q, is obtainable mathematically by substituting eq. (2) in eq. (1), and differentiating. The resulting equation, however, is too long for practical use, and can be solved conveniently only by the tentative process. The joint of least stability is generally in the larger shafts at about half of their height above the base, but in small shafts it descends sometimes as low as a few feet above the ground.

The greatest pressure of the wind is taken in Great Britain at 55 lbs. to the square foot. Unfortunately, we have no records as to the maximum pressure experienced in these latitudes, and in fact in not any latitudes accurately. The experiments of Smeaton are the only ones given in scientific works. The writer is inclined to think that no hurricane presses here with a greater violence than 45 lbs. to the square foot, an enormous pressure when well appreciated, and that this figure would suit most localities on both continents. Yet in view of the uncertainty on this point, he would recommend, on the ground

of safety, the English practice of using 55 lbs. for the greatest pressure of the wind per square foot. This is a figure which he has himself employed with economical results.

In the case of light-houses, the portion not exposed to the shocks of waves during storms may be calculated by the foregoing principles. The lower part may be formed either as a pedestal sufficiently massive to resist the greatest violence of the sea, or in a monolythic mass by the usual means.

We will illustrate the preceding investigation by an example, and shall choose the St. Rollox chimney as an instance well known. As actually constructed, this shaft has a variable batter on the outside, which differing *very little* from a straight batter, may be considered quite properly as such. On plotting the chimney and drawing a batter line as near as possible through the reëntrant angles of the steps on the inside, we deduce the following data to obtain the value of tan α:

$$a = 11.9', b = 13.5', \tan \alpha - \tan \beta = .004'.$$

The total height $= 435.5'$, the pressure of the wind per sq. ft. $= 55$ lbs. $= p$, and the weight of a cu. ft. of brickwork we will take $= 118$ lbs. $= u$. We know also the thickness at the base, which is:

$$435.5 \times .004 + \tfrac{1}{2}(13.5 - 11.9) = 2.54'.$$

We have by substituting in the equation, changing the sign of tan β, and assuming $q = \frac{1}{4}$:

$$y = \frac{\frac{55}{118} 435.5^2 (40.5 + 871 \tan \alpha)}{\frac{(13.5 + 871 \tan \alpha)^3 - 13.5^3}{\tan \alpha} + \frac{11.9^3 - (11.9 + 871(\tan \alpha - .004))^3}{\tan \alpha - .004}} =$$

$$\tfrac{1}{4}(13.5 + 871 \tan \alpha).$$

This equation reduced leads to:

$$1276.5 \tan^3 \alpha + 1498.5 \tan^2 \alpha + \tan \alpha - 2.05 = 0.$$

From which, by a few trials:

$$\tan \alpha = .036.$$

The other two values of tan α are negative, as indicated by the sign of 2.05. Knowing tan α, we have for the diameter of the base, $44.86'$. This diameter, as actually built, is only $40.00'$. The cause of the dis-

crepancy we will investigate further on, and proceed now to determine the position of the line of resistance. With this object in view we will assume $x = 100$, $x = 200$ and $x = 300$, and deduce from eq. (1) the corresponding value of y:—

$$y = 5.7,\ y = 8.7,\ y = 10.6.$$

We have, therefore, with the points at the summit and base of the shaft, altogether, five points of the line of resistance in order to draw it in. In actual practice, we would need a few more to produce accurate work. These should be obtained in the neighborhood of the joint of least stability. However, with our data this joint is found to be about 200 feet from the top of the chimney.

The discrepancy noticed above indicates only that the value of q is a little larger than 0.25, at which we assumed it. To determine it accurately, we substitute in equation (1), in addition to the foregoing data, the value $\tan \alpha = .0304$ taken from the plot and solve it with respect to y. We thus deduce:—

$$y = 11.41' \quad \therefore \quad q = 0.285.$$

As this value of q falls considerably within the limits set down, we may therefore feel assured of the stability of this elegant construction.

Many engineers, in order to save some material, may be tempted to use q as large as possible, and surpass the limits we assigned to it. But let it be remembered that we should provide sufficiently against any obliquity in the axis of the shaft, resulting from imperfect workmanship, from any irregular compression in the foundation, or from any unequal settlement in the lower joints, caused by the shaft being built too fast. Provision must also be made, by keeping in the line of resistance, against the compressive strength of the material on the outside of the shaft being tested beyond its endurance, which will be fully tried when the shaft is put in vibration by a succession of hard blasts of wind. This remark applies particularly to brick and the softer stones. In conclusion, we may notice that the strength of an intended shaft may be increased either by augmenting the base or the thickness of the shell. Of course, the augmentation in either direction is limited by other requirements, and is not indefinite.

Chemistry, Physics, Technology, etc.

ON SOME RECENT IMPROVEMENTS IN THE MANUFACTURE OF ARTIFICIAL STONE, AND THE APPLICATION OF SUCH STONE TO CONSTRUCTION AND OTHER PURPOSES.

By Frederick Ransome, Esq. C. E.

(A Paper read before the Franklin Institute, November 10, 1873.)

Being on a visit to this country with a view to the introduction of a process for the manufacture of stone, which has been successfully employed in England and in other parts of the world, the author has been kindly invited to read a short paper upon the subject at this Institute.

It may be desirable at the outset to state that it is not the object of this paper to treat of the many various methods for making artificial stone which have from time to time been brought before the public; their name is legion, and their several natures and properties have already been dealt with by abler and perhaps more disinterested investigators. Therefore, whilst recognizing peculiar merit in many of such methods, and appreciating advantages they have severally afforded in the arts, both of construction and ornament, when properly applied, the author will allude more particularly to those in which he is more directly interested, to the perfection of which he has devoted the greater portion of his life, and which he believes are, in most respects, essentially different, both in the details of their manufacture, and in many of the various purposes for which they are especially designed.

The progressive development of the natural world, through periods which occurred long before the dawn of the most remote traditions of antiquity, have placed at the disposal of man materials which for the most part eminently subserve the various purposes of construction and decoration. These materials, however, such as the granites, marbles, sandstones, limestones, so occur in isolated groups, in some instances so remote from the centres of civilization, the cost of labor in working into form, and the consequent waste of the material itself so great, as to render them prohibitable for general use, except in local situations.

The requirements of man soon demanded a material which should approximately fulfil the conditions of stone in the construction of their buildings, and this necessity was in the earlier ages supplied to a great extent by the manufacture of bricks, concrete, etc.

The advantages afforded by these substances were readily recognized by the ancients, and have been fully appreciated in modern times; but great as these advantages are in a constructive point of view, they fall very far short of the requirements of the present age.

It is therefore no matter for surprise that numerous attempts have been made from time to time to supersede or supplement the productions of nature by the imitations of art, and the importance of producing a material combining all the merits, without having the defects, of the most useful building stones, and at the same time possessing advantages peculiarly and specifically its own, was long since recognized by the author, and he adopted the task of solving the problem of manufacturing a stone which should economically answer, at least, some of the varied purposes of the products of nature.

He commenced his investigations into the nature and properties of stone just thirty years since, and he found, that with comparatively few exceptions, the hardest and most durable were those in which silica abounded, either in the form of quartz or crystals, or in combination with lime or other substances. With this fact in view, he commenced a series of experiments, and selecting silicious sand (composed of crystals of nearly pure quartz, and which may be obtained in abundance in almost all parts of the world) as a base, he proceeded to combine the particles by the admixture of a small proportion of powdered glass and clay under hydraulic pressure, and subsequently more completely uniting the mass by partial fusion. After numerous unsuccessful attempts, and after having, as he believed, exhausted the various combination of sand, etc., with almost every known cement within his reach, it occurred to the author to substitute a concentrated solution of silicate of soda or potash for the other cementing materials he had previously employed. Sand, when mixed with this solution of silicate of soda or potash, and pressed into a mould, formed, when dried, a very hard stone, having a close and uniform texture, but which, however, became disintegrated upon being exposed to moisture. The next step was to submit the compound to the action of heat, when the free alkali of the cementing silicate, combining with an additional quantity of the silex of sand, produced an insoluble silicate unaffected by moisture. The author obtained his first English patent for this process in 1844, and immediately established works for the manufacture of what was then known in the market as the "Patent Silicious Stone." Such were in general the results obtained and such, with various modifications in points of detail, was

the process adopted by the author in manufacturing stone for many years.

The stone thus prepared was found to be very hard, of beautiful texture, and perfectly indestructible by atmospheric influences or acid vapors. Many illustrations confirmatory of this statement may be seen at the present time, where the "Patent Silicious Stone" has been exposed to the most vitiated atmosphere in London, the finest edges and tool marks upon which are still as sharp as when they first left the manufactory. There were, however, serious practical objections to this mode of manufacturing, which will at once occur to the minds of many present—the operation was at once both tedious and expensive. Special care and considerable time had to be taken to drive off all superfluous moisture before the articles were placed in the kiln, in which the heat had to be generated and reduced very gradually; the risk of flaws and of cracking formed a very serious item in the process, and after all care and expense which could be expended to prevent the failures alluded to, it was found to be practically impossible to secure truth of outline, or, in other words, to prevent distortion by the expansion and contraction produced in the process of burning. The next problem was to determine how to convert the soluble silicate of soda into some insoluble silicate, which should possess the properties requisite for the formation of a good, hard, compact and durable stone without the action of fire heat, which had been found so inconvenient and expensive in the former methods.

In the year 1856 the author secured letters patent in England for a means of rendering stone, bricks and other building materials less liable to decay by first saturating these with a solution of silicate of soda, and afterwards applying a solution of chloride of calcium, which immediately decomposed the former, and produced an insoluble silicate of lime in the stone, etc., so operated upon; and in the year 1861, in consequence of the premature decay of the stone of the new Houses of Parliament at Westminster, a special committee was appointed by Government to examine and report on the causes of such decay and the best means of preserving the stone from further injury. The author, in common with others, was summoned to attend, and give evidence on the subject; and after stating the satisfactory effects produced upon the stone of some of the buildings upon which he had operated, he proposed that, in order to demonstrate more conclusively the efficiency of the process, that a piece of the stone should be reduced to powder, and then, by the aid of the two solutions of

silicate of soda and chloride of calcium, to reconvert the powder back into a solid stone.

The experiment was tried, and the result was so completely successful that the author immediately applied for a patent for the manufacture of stone by the employment of the above and similar ingredients, which patent was accordingly sealed in England on the 3d of October, 1861. Arrangements were at once made for the manufacture of stone upon a large scale by this process, which, in order to distinguish it from the "Patent Silicious Stone" already described, is called the "Ransome Patent Stone." This material, in which sand and silicate of soda, etc., after being thoroughly incorporated in a suitable mixing mill and moulding into the form required, is saturated with a concentrated solution of chloride of calcium, by exhausting the air by means of air pumps, or by forcing the solution through the moulded mass by gravitation or otherwise. Double decomposition of the two solutions immediately takes place, resulting in the production of an insoluble silicate of lime, firmly uniting and enveloping all the particles of which the mass is composed, and a solution of chloride of sodium or common salt, which is subsequently removed by the free application of water. This description of stone has now been extensively used in England during the past twelve years, and the demand for it is very rapidly increasing for all kinds of building details, especially for those of an ornamental or artistic character. It is perfectly free from all liability to distortion or shrinkage, is unaffected by any variations of climate or temperature, and is uniform and homogeneous in its texture. It has been most successfully employed in various countries abroad, especially in India, where the Government has established works for its manufacture. It has also been employed to a considerable extent in this country, especially in Chicago and San Francisco, where it is successfully manufactured. There are upon the table several specimens of this stone which were manufactured at the works of Messrs. Wright & May, at Chicago, and which bear a very favorable comparison in appearance with the best descriptions of the natural stones of this country. Its cost is less than half that of natural stone in details of an ornamental character, especially where there is much repetition, and its enduring quality is now so fully established as to need no comment.

When the author visited Chicago a few weeks since, he inspected several buildings which have been erected since the calamitous fire of 1871, faced entirely with the Ransome stone, manufactured by Messrs.

Wright & May, which may easily be mistaken, by a casual inspection, for the marble of the district, and he was informed, upon reliable authority, that there were about two hundred buildings in the city in which the "Ransome stone" had been employed for dressings or finishings, and although the thermometer was as low as 27° below zero during last winter, it stood perfectly uninjured.

Dr. Ed. Franklin, in writing upon the Ransome stone, says, "I am induced to believe that Mr. Ransome has invented a material which, with the exception of the primary works, is better capable of giving permanency to external architectural decorations than any stone hitherto used."

Dr. A. Snowden Piggot, Analytical Chemist, Baltimore, says—"Double decomposition ensues, and a silicate of lime of a glassy hardness and imperviousness coats every grain and binds the whole into one solid mass. Such a stone carefully made may be considered proof against all ordinary atmospheric influences."

Professor Ansted states—"A parallel bar of Ransome's stone, 4″×4″, resting on iron frames so as to bear one inch at each end, with sixteen inches clear between the supports, sustains a weight suspended from the centre of 2122 pounds. A 4-inch cube of Ransome's stone sustained a weight of thirty tons before it was crushed."

One more special application in which the Ransome stone has proved eminently successful may suffice, viz., in the manufacture of grindstones, which surpass in their cutting properties all those of the natural stone in comparison of which they have been tested.

With a view fairly to test the comparative grinding power of these stones, Messrs. Donkin & Co. constructed a simple apparatus by means of which an equal and uniform pressure could be exerted upon pieces of steel presented to the faces of the several grindstones. The pieces of steel were cut off the same bar, and were accurately weighed before the operation; the grindstones were then set in motion. The Newcastle stone ground away a quarter of an ounce of steel in eleven hours. The "Ransome stone" ground away a quarter of an ounce of steel in sixteen minutes. The same description of stones are now largely used in England for shelling and cleaning rice, and for grinding and rubbing purposes generally, and are exported to all parts of the world.

The foregoing is a brief history of the material manufactured by the author down to 1870, at which time he developed another process as distinct from the last described as was that from the one patented

by him in England in 1844; and for which he obtained another patent in England in October, 1870, and a subsequent patent in the United States in 1872. This latter process, for the sake of distinction, is called "Ransome's Apœnite."

It was found in practice that the process of washing the "Ransome stone" so as completely to remove all trace of the chloride of sodium from large masses, was open to objection; it was both tedious and expensive, especially in localities where there was a difficulty in obtaining a good supply of tolerably pure water at a reasonable cost; besides which, in producing so large an amount of chloride of sodium, which had to be afterwards removed from the stone as a waste product at considerable cost, the bulk of the alkali, which was by far the most expensive ingredient in its composition, was ejected instead of being utilized, for still further increasing the density, strength and hardness of the stone.

This defect had for a considerable time engaged the attention of the author with the view of effecting a remedy, and step by step it has been accomplished by a process so simple and in a manner so satisfactory in its results, as to leave little or nothing to be desired.

Some years since a silicious deposit was discovered at the base of the chalk hills in Surrey, possessing some very peculiar properties, amongst others, that of being readily soluble in a solution of caustic soda or potassa, at a moderately low temperature.

Taking advantage of this peculiarity, the author commenced a series of experiments, in order to determine if it were not possible, without the use of chloride of calcium, to produce a stone in all respects equal in quality to what had hitherto been made, and in this he has now succeeded, by mixing, in lieu of the chloride of calcium, suitable quantities of lime (or substances containing lime) and the natural soluble silica above alluded to, with sand and a solution of silicate of soda or potassa, which, when intimately incorporated, are moulded as heretofore, and allowed to harden gradually as silicate of lime is formed by the decomposition of the alkaline silicate produced by the action of the lime. The mass gradually becomes thoroughly indurated, and in a very short time is converted into a very compact stone, capable of sustaining extraordinary pressure, and increasing in strength and hardness with age.

The chemical actions which produce these results appear to be as below stated. When the before-named materials are mixed together, the alkaline silicate is immediately decomposed, the silicic acid com-

bining with a portion of the lime present, forming a silicate of lime, whilst a portion of the alkali in a caustic condition is set free; this free alkali immediately seizes upon the natural soluble silica which constitutes one of the ingredients, and thus forms a fresh supply of silicate of soda, or potash, as the case may be, which is in its turn also decomposed by a fresh qaantity of lime; and so on.

If each successive decomposition of the alkaline silicate resulted in setting free the whole of the alkali, these decomposing processes would continue so long as there remained any soluble silica present with which the alkali could combine, or until there ceased to be any free lime to decompose the silicate of soda or potash when produced; the termination of the action being marked by the presence in the stone of the excess of caustic alkali on the one hand, or of alkaline silicate on the other. In reality, however, the whole of the alkali does not appear to be set free as the soluble silicate is decomposed by the lime, there appearing to be formed a compound silicate of lime and soda (or potash), whereby a portion of the alkali becomes permanently fixed at each decomposition. The result of these several changes is that the whole of the alkali is gradually fixed, and none remains to be removed by any subsequent washing or other process.

The tenacious and enduring properties of silicate of lime are too well known to need any elaborate explanation in this paper. It is the substance which has conferred upon the old Roman mortars and concretes the enormous hardness they are found to possess even after a lapse of 2000 years and upwards.

Upon close examination of a piece of the old Roman concrete, we find that the hardest part of such concrete is not the lime with which it was combined, nor even the flint stones combined therewith, but the hard shelly film which has formed over the external surfaces of these stones, caused by the action of the lime with which they were in contact, and which is silicate of lime.

From the foregoing remarks it will be apparent that, in order to produce the most satisfactory results in the manufactory of artificial stone of the character of that now under consideration, special attention should be paid to the selection of suitable materials, and great care should also be observed in details of manipulation. The sand employed should be clean, sharp and silicious, free from argillaceous or cretaceous matter. The natural soluble silica exists, in large deposits, in various parts of the United States, and can be supplied in considerable quantities for manufacturing purposes, at a compara-

tively low price; but it must be borne in mind that these natural soluble silica deposits vary very considerably in the amount of their solubility; and, for the purpose of making the "Apœnite" stone, that which is most soluble in a given solution of caustic soda at a given temperature should be selected. Through the kindness of Dr. T. Sterry Hunt, of Boston, the author has received a sample of silicious earth, upwards of 90 per cent. of which is readily soluble, whereas several other samples from other localities have not furnished more than 40 per cent. under same conditions.

The silicate of soda also requires to be prepared with due regard to the proportions of silica and soda respectively, that containing 66 per cent. of silicic acid with 34 per cent. of soda being found in practice to produce the best general results. A sample of silicate of soda, furnished by Dr. Feuchtwanger, of New York, is now on the table, and appears to meet such conditions.

Very much also depends upon the selecton of the lime to be employed; and perhaps there are few articles of every-day consumption sold under the same name that differ more widely in their compositions and properties than limes and cements. These substances have been most thoroughly investigated, and the results published by Gen. Gilmore in his very useful "Practical Treatise on Limes, Hydraulic Cements and Mortars," and need only be alluded to in the present paper for the purpose of drawing attention to that which appears to be most suitable for the operations herein described. Amongst these may be selected that known as the hydraulic lime of Teil, and which derives its hydraulic energy from the large percentage of silicate of lime in its composition, viz., 66 per cent. It is slow in setting, thus affording time for proper manipulation in the process of stone-making, and attains high tensible strength, with great power to resist a crushing force. Its hydraulic properties have been largely tested in the construction of the marine works at Marseilles, Alexandria, and other seaports, as also in the great breakwater at the entrance to the Suez Canal and in the Mont Cenis Tunnel. Samples of this lime have been furnished to the author by Messrs. Champin & Gillet, of New York, who are the sole agents of the manufacturers for the supply of this lime in North America; there is also on the table a small fragment of concrete taken from the harbor works at Marseilles after having been submerged 23 years.

Well-burnt Portland cement, of good quality, may also be advantageously employed, instead of lime of Teil, where now immediate

setting of the mass is required; but so many manufacturers of the so-called Portland cement have of late years sprung into existence in consequence of the increased demand for this article, and so much competition has been excited for the production of an hydraulic cement under this name at a low price, that more than ordinary care should be observed in its selection. The best Portland cement is composed of a mixture of white chalk and an alluvial deposit of rivers in a state of minute division, which substances, after being intimately incorporated mechanically, are burnt in a kiln to a point almost approaching vitrifaction, and afterwards ground and sifted, by which means a compound silicate of lime and alumina is formed, possessing the high hydraulic properties for which the Portland is so famed; but unless these ingredients be so mixed and burnt as to be chemically combined, instead of being merely mechanically incorporated, the so-called Portland cement may be worse than useless, and the employment of such material may lead to very disastrous results.

As comparatively few of the many persons who employ this material have any sufficient opportunity of personally ascertaining its essential properties, it is safer to rely upon the productions of such makers whose experience in the manufacture, and whose recognized standing in the commercial world form a sufficient guarantee for a genuine article.

Unquestionably there are such manufacturers upon the value of whose productions every reliance may be placed, amongst which, with many others, may be mentioned the names of Messrs. Vicat & Co. and Messrs. Lafarge, in France, and Messrs. White Brothers, the Burham Cement Co., and others in England, who have justly acquired a world-wide reputation. There may also possibly be makers of Portland cement of good quality in this country, but the author's experience has been far too limited to enable him to speak practically as to them.

Having explained the manufacture and chemical composition of the several descriptions of artificial stone herein alluded to, it will be as well in the next place to point out some of the varied purposes for which the "Apœnite" process is more especially applicable. The primary condition of materials for construction are, unquestionably, strength and durability, those of a secondary nature being appearance, facility of application to the intended purpose, and economy in use. As regards strength, it has before been stated that the stone manufactured by the "Apœnite" process increased with age. By some

experiments which were made for the purpose of testing their possession of this quality, numerous samples were proved, within a month of their manufacture, to be superior to Portland stone. At the age of ten weeks the strength of "Apœnite," as compared with Portland stone, was found to be as 7145 lbs. to 2630 lbs. per square inch, and as compared with Bramly Fall, 7145 lbs. to 5120 lbs. per square inch. As regards durability, the well-known properties of the materials employed in its manufacture must serve as a sufficient guarantee upon this point until time should have offered corroborative and conclusive testimony.

In general appearance, the Ransome stone bears such a perfect resemblance to the natural sandstones as to mislead the most critical observers, whilst the facility of application and its economy in use will have been apparent from the foregoing description. By the last-mentioned process the field has been widely extended for the useful application of the "Apœnite" stone produced thereby. It is now no difficult task to produce blocks of this material of any form and of any size, the only limit being the means available for lifting them upon the spot where they are to be employed. Moreover, the greater part of the material required for its manufacture are, as a rule, generally to be found in abundance where hydraulic or other important works are being carried on, and for which purposes this new stone is eminently suited.

The want of such a material for such purposes has long been felt, although that want until recently has only been partially supplied. In the year 1870, Mr. Jas. W. Butler applied for and obtained a patent, in England, for improvement in the application of concrete to structures and foundations, and also to coffer-dams and similar constructions. Mr. Butler's obvious desire was in the first place to provide a cheap and efficient substitute for stone for hydraulic operations, and in the second to render unnecessary the construction of false works, etc., and thus to avoid the expense connected with the employment of iron cylinders, hitherto so extensively used. The idea was certainly an excellent one, but its practical realization appeared very remote until Mr. Butler's attention was directed to the new "Apœnite" stone, as a material necessary for the successful development of his proposed methods of construction. He accordingly communicated with the author upon the subject, and an opportunity was soon afforded for applying a practical test for the solution of this important question. Some extensive operations were at this time be-

ing carried out on the banks of the Thames in the construction of a retaining wall, to protect the fore shore at Hermitage wharf, under Mr. Butler's superintendence. Cast iron cylinders, 8 feet in diameter, were specified to be sunk, to form the face of the wall next the river, and the work had proceeded towards completion when, in consequence of the strike on the part of the workmen, and the sudden rise in the price of iron, considerable delay and difficulty was experienced in procuring the iron cylinders. In this dilemma Mr. Butler suggested to the engineer-in-chief (A. M. Rendel, Esq.), the employment of cylinders of "Apœnite" for the completion of the wall. The author was at once communicated with by that gentleman, and the order was given accordingly. The cylinders were 8 feet external diameter and 9 inches thick, made in lengths of about 4 feet each; when only a few days old they were sunk in the usual manner without any difficulty, and the result was so satisfactory to Mr. Rendel that in a letter he wrote to the author on the subject he expressed his regret that he could not have more of them. The arrangement proposed for economically carrying out this class of work is shown in the diagram. A timber staging is erected, upon which the materials may be mixed and moulded, the moulds consisting of an inner and outer framing, the space between the two forming the mould for each ring for a cylinder or hollow block, as the case may be; the courses are joined by means of a cement formed of similar material to that of which the rings or blocks are composed. These are lifted from the staging on which they have been made, and lowered into position by an over-head traveller or crane, as may be most convenient. The lowest course of the cylinder or hollow block is chamfered, as shown in the diagram, and when necessary, from the nature of the soil, may be shod with iron. The operation of sinking is carried out in a precisely similar manner to that adopted with iron cylinders. The horizontal joints are made with alternate projections and depressions, and the several courses are connected vertically by dowel piles, which also serve as guides in sinking the work. The application of this principle is capable of modification to suit almost every variety of construction, and it will be found especially applicable in structures requiring heavy foundations, particularly where the ground is uncertain or treacherous. For forming a face wall in building quays or docks, instead of cylinders, rectangular hollow blocks or caissons may be used. By employing hollow blocks of hexagonal form no interstices are left, a thin layer of the cementing material rendering the structure practically homogeneous.

Cylinders constructed upon this principle are also adapted for deep wells, apertures being formed in the sides for the admission of water. Turning to works of greater magnitude, it will be seen that "Apœnite" forms a peculiarly suitable substance for the construction of bridges, sea walls, piers and similar undertakings. In the case of piers for bridges the structure can be carried up to the underside of the bridge girders or built with ordinary masonry above high water level.

For sea walls or piers the arrangement shown in plan and section could be adopted. Here two rows of caissons are employed separately from each other longitudinally, the intermediate space being filled in with dry rubble hearting, and the blocks themselves with a similar material, or, if necessary, with concrete.

The author has recently inspected some works which are now in progress in this country, in which large blocks of Portland cement concrete are employed in the construction of the river wall. These concrete blocks, some of which are of the following dimensions, 14 ft. × 10 ft. × 5 ft. 6 in. = 77 cubic feet, weighing about 56 tons each, are moulded into form at a distance of upwards of two miles from the spot where they are finally to be deposited, and which, when sufficiently hardened, are transported by barges or floating derricks to their place of destination, where they are deposited in the ordinary mode of construction. If, in the place of these solid blocks of concrete, hollow blocks or caissons of "Apœnite" stone are constructed according to the design shown upon the accompanying plan, and after being placed in position were to be filled with good cement concrete, and backed with the same, the "Apœnite" blocks being firmly bonded together, as shown, and the concrete forming one entire mass throughout, the structure would be perfectly monolithic, and so thoroughly compacted together that it would be impossible to disturb the position of one part without exerting such a force as would be necessary to destroy the whole. In the accompanying sketch the dimensions of the proposed hollow blocks are shown as 24 ft. × 12 ft. × 6 ft., the "Apœnite" being 18 inches thick on the two sides, and 12 inches thick on the ends, each block being 6 feet high and measuring in external dimensions 1728 feet cube, of which 532 feet cube only will be composed of the "Apœnite" stone, and 1196 feet cube would be composed of the concrete filling. The "Apœnite" hollow blocks of the above dimensions, which would weigh about 40 tons each, may be made in any convenient place, and can be readily transported to the works where they are required to be permanently depasited, and will therein occupy more than three times

the space of the present solid concrete blocks, whose cubical content is 30 per cent. greater.

In the case of an embankment for a reservoir, the heart of the bank, which is usually made with a puddle wall, is proposed to be substituted by two rows of "Apœnite" cylinders, the contained spaces being filled in with puddle, and the cylinders themselves with material similar to that of which the bank is made. This arrangement is also illustrated in the accompanying diagram. In sinking the cylinders they would be carried some distance below the natural surface, so as to obviate any chance of leakage below.

It is obvious that this plan could, without much difficulty, be applied to embankments already constructed where there was reason to apprehend that any settlement had occurred. By sinking the cylinders from the top through the puddle bank, but without removing any of the slope on either side, they would be carried down to sound ground, rendering the embankment safe, and removing all fear of danger in the future. A cheap and effective coffer-dam is also shown. Such a dam could be constructed under ordinary conditions, at a cost considerably below that of any other effective material. It would not be difficult to multiply instances in which this material can be practically employed; but enough has already been said on this point. An artificial stone combining the advantages of "Apœnite," one moreover which can be so readily moulded into any form or size with but small expense and little or no delay, and, moreover, one that is practically "fire-proof," is necessarily applicable to a great variety of uses. The author will therefore only briefly remark upon its applicability for ornamental and decorative purposes.

When prepared with suitable materials, the "Apœnite" is capable of receiving the most delicate impressions, and by the incorporation of the different metallic oxides, any variety of color can be imparted to it, so that artificial marbles or granites of almost every description can be produced. The artificial stones, like their originals, are capable of taking an excellent polish, are extremely hard, and can be readily moulded into the most elaborate forms, at a very small cost.

The author would only briefly allude to the testimony that has been borne to the value of the Apœnite process by engineers in England, whose names must be familiar to many of the present company, viz., Messrs. Hawksley, Hawkshaw, Bramwell, Vignoles, etc. When the author had the honor to read a paper on the subject before the mechanical section of the British Association last year, at which the Presi-

dent, at the close of the discussion which ensued, remarked, "I cannot refrain from saying that I believe the process of making artificial stone which Mr. Ransome has invented and perfected, is of very high importance indeed, that it has given to the world a new material which will be of great service, as well for the structural works of the engineer and architect as for purposes of ornamentation, and is eminently calculated to subserve many useful and important purposes in the industrial arts."

It now only remains for me to return my sincere thanks to you, sir, for affording me this opportunity of bringing my inventions under the notice of the members of this scientific institution, and to you, gentlemen, for the patience and courtesy you have extended to me in listening to the paper I have just had the honor of reading. I am aware that it contains many imperfections, which, however, I trust the subject of which it treats does not possess, but I must claim your indulgence, as it has been written in very great haste and without such materials at my command as I would have desired to enable me to illustrate the subject more fully. I, however, can only add that I shall be happy to supply any further information in my power verbally that may have been omitted from the body of the paper, and to answer any inquiries that may arise in the course of the discussion which I understand is now intended to follow.

DISCUSSION.

Mr. HENRY CARTWRIGHT inquired of Mr. Ransome whether the artificial stone had ever been employed in the construction of piers for bridges or dock walls made in slabs set on edge, instead of in the cellular form, as shown in the diagrams.

Mr. R. replied that it had not been thus employed, as there would be some practical difficulty met with in that form, in securing the sides and ends of such blocks to retain the concrete filling.

The PRESIDENT.—In the manufacture of your Apœnite, is not the peculiar soluble silicious earth employed, that which is known as diatomaceous or infusorial earth?

Mr. R.—The so-called infusorial earth is excellently suited for the purpose, though we have found very suitable materials which bear no evidence of infusorial origin. In this country such deposits are quite frequent. It is found abundantly near Richmond, in Virginia, in the neighborhood of Boston, and in several parts of California; and doubtless, should the necessity for its use become generally

appreciated, it could be detected in numerous other localities. I must beg here to express my obligations to many scientific men, whom I have met in this country, and who have greatly aided me by sending samples of such materials for my investigation or by referring me to new localities where they may be found.

Mr. JOHN SARTAIN asked whether it was applicable to the sculptural decoration of the exterior of buildings, and to all that class of artistic work in which terra-cotta is now extensively employed in continental Europe. For example, bas-relief panels or slabs of ornaments or groups, whether in low or high relief. The inquiry had special reference to the sculptural decoration of an important building to be devoted to art purposes, now in course of erection in Philadelphia.

Mr. RANSOME replied that it was; that it had been used not only for enriched copings over doors and windows, but also for capitals of corinthian columns, instanciug a new hospital building at London, erected on the river bank.

The PRESIDENT.—Does the Apœnite suffer any subsequent efflorescence?

Mr. R.—None at all. By the new process no washing is required, as is necessary with the "Ransome Stone." So long as sufficient soluble silica and lime are present in the materials, the whole of the soda is combined, and thus none is left free to effloresce. At each successive chemical action which occurs during the process of formation, a portion of the free soda becomes fixed. It is therefore only necessary to observe carefully the correct proportion of the several ingredients before mixing, in order to insure perfect freedom from this difficulty. I may mention also, incidentally, that the color of either of the stones may be varied at pleasure. By employing a light sand a light colored rock is obtained, with dark sand the reverse; or any color may be imitated by the employment of suitable metallic oxides. If, in connection with the foregoing, it is remembered that fragments of various degrees of coarseness may be employed with the sand, it will be perceived that the appearance of any of the natural stones may be closely imitated.

Mr. WM. V. MCKEAN.—I should like to be informed of some of the mechanical details of the manufacture of the stone.

Mr. R.—Mr. Ransome said that these were quite fully stated in the body of the paper.

Mr. ——— inquired whether the chloride of calcium process was still in use.

Mr. R.—Yes, quite largely, both abroad and in the United States. One good reason for its continuance, aside from the fact of the quality of the stone, is that the plant is there. The last process (apœnite) is, however, beyond question, the best.

Mr. ——— inquired how the stones stood the test of fire.

Mr. R.—Both the Ransome stone and the apœnite stand the fire well. They may be heated to redness without injury or material deterioration of their strength and hardness. The apœnite, however, seems to stand this test better than the other; in fact, so well does it act in this particular that it would be quite practicable to make gas retorts of it.

Mr. ———. —What is the best material, with your process, for making the moulds for caps and columns?

Mr. R.—Plaster of Paris is found generally most convenient. Where we have our choice, however, and the nature of the work permits of it, we use wood.

The PRESIDENT.—Are emery wheels made by the last process?

Mr. R.—Yes; very largely.

Mr. SELLERS.—When the "Ransome Stone" first began to be spoken of here, and the accounts of the method of working it were described in (I think) "Engineering," it seemed to me that the process might be utilized in forming emery wheels, which could be used either with water or oil. With this view we tried a number of experiments, and some wheels made by us on the Ransome plan were actually used in practice, but proved to have only a surface, wherein it is probable we did not get a perfect saturation of the chloride of calcium. We did, however, make some very pretty specimens of stone experimentally with various kinds of sand.

Mr. R.—The difficulty the President refers to was without doubt caused by the fact that, as the stone was made which he employed, the chloride of calcium was not made to penetrate into the interior, but simply affected the stone to a slight depth, while within, the same remained comparatively soft. Where the air-pump is employed, this material can readily be drawn through blocks of a foot or more in thickness, and this plan is invariably followed in the manufacture of this stone.

Mr. F. C. PRINDLE inquired if the stone was much used for drainage purposes.

Mr. R. replied that in the most instances bricks and similar materials were found to be cheaper.

Mr. F. C. PRINDLE.—What is the relative cost of the two kinds of stone?

Mr. R.—The cost of the apœnite will generally be about two-thirds that of the "Ransome Stone," but comparisons are difficult, inasmuch as this estimate will suffer many variations according to locality. Where the chloride of calcium can be obtained cheaply and in abundance, as in England, where it is a utilized waste product, the cost of the "Ransome Stone" will be moderated; while, on the other hand, the cost of the apœnite will depend largely upon the abundance and availability of suitable deposits of soluble silicious earth, &c.

Mr. PRINDLE.—Is it more possible to use coarse sand with the apœnite than with the other stone?

Mr. R.—Coarse sand may be used with both. Indeed we are often glad to use very coarse materials.

Mr. EDWARD TILGHMAN wished to know the difference between the so-called Victoria stone and those described by Mr. Ransome, or if the Victoria stone was not an invention of Mr. R's.

Mr. R.—I am happy to say that it is not the same. I am, however, fully acquainted with the history and process of the invention of the Victoria stone, since the inventor is a personal friend, and I was consulted before the application was made for the issue of a patent, because the claims upon some points might be construed to conflict with those of my own patents. The inventor uses sand in connection with Portland cement; broken granite, &c., is also employed. The mould with the plastic stone is then immersed in silicate of soda solution. Thus silicate of lime is formed at the surface of the block. I do not wish to be understood as disparaging in the least the value of this process, since most excellent results have been achieved by it.

At the close of the discussion Mr. Washington Jones moved that the thanks of the meeting be presented to Mr. Ransome for his most interesting and exhaustive paper. The motion was unanimously adopted.

Mr. Ransome, in acknowledging the vote of thanks, remarked that he had experienced so much kind attention from the members of the Institute, and such unexpected interest on their part in what he feared would prove uninteresting to them, that his thanks were due to them, rather than the reverse.